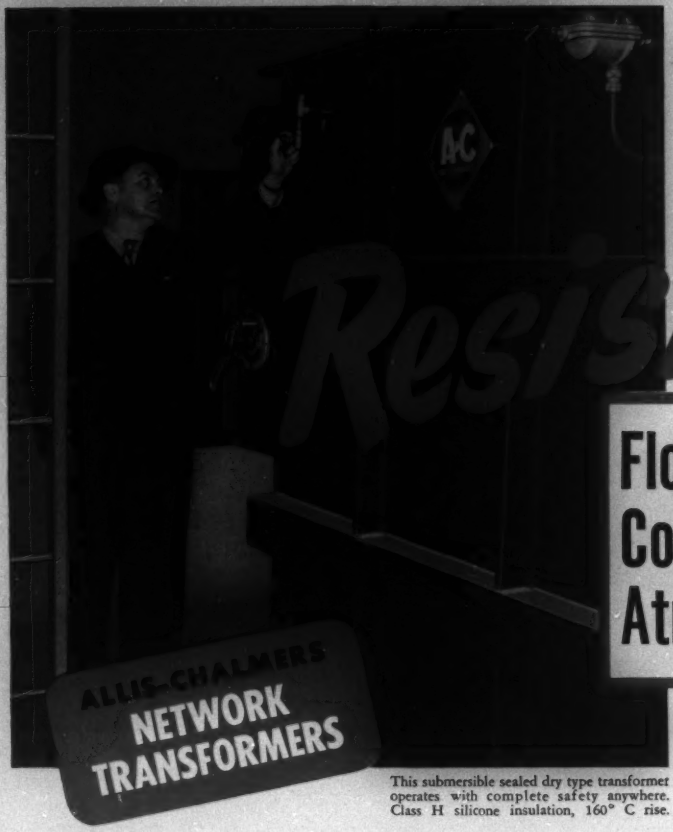
ELECTRICAL ENGINEERING

MAY
1951

SUBMARINE
CABLE
CENTENNIAL

GREAT LAKES DISTRICT MEETING, MADISON, WIS., MAY 17-19, 1951



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IN MAJOR ELECTRICAL systems coast to coast the A-C trademark on network transformers is a familiar sight. Wide acceptance of these transformers is no accident.

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OIL FILLED. Widely used because of over all economy and proved dependability. High in efficiency and reserve thermal capacity. Vault or subway types.

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NEW SEALED DRY TYPE. Thanks to class H insulation no coolant necessary. Requires no internal maintenance. Eliminates fire and explosion hazards. Hermetically sealed.

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MAY 1951

The Cover: The cable ship, *Lord Kelvin*, of the Western Union Telegraph Company, laid the cables for the Key West–Havana submarine telephone cable system. The bottom half of the cover shows the submerged repeater described in the article, "A Submarine Telephone Cable with Submerged Repeaters," by J. J. Gilbert (*EE, Mar '51, pp 248–53*).

Photograph courtesy Bell Telephone Laboratories

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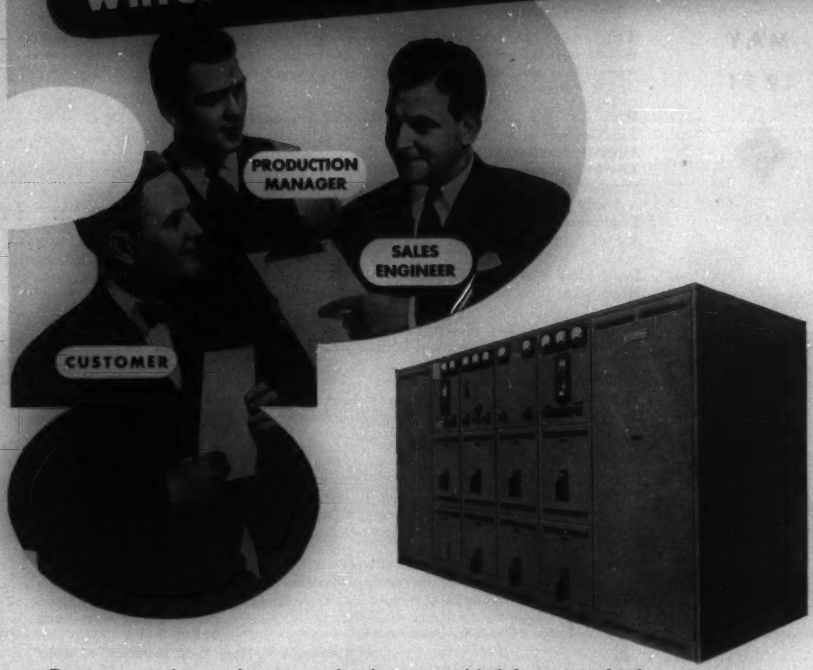
WHICH MAN IS THE EXPEDITER?



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HIGHLIGHTS.....

What to Do About Shortage of Engineers? President LeClair suggests three fundamental approaches to overcoming the problem of the shortage of engineers in industrial and military fields. Then he discusses ways of maintaining a continuing supply of engineers. Most important is that an engineer's time and talents not be wasted in unproductive or nonengineering work (*pages 377–78*).

The Genesis of Submarine Cables. Lloyd Espenschied of the Bell Telephone Laboratories, Inc., reviews the historical events preceding the laying of the first submarine cable in 1851, and the subsequent developments in the field of communications (*pages 379–83*).

Aircraft Navigation. Many of the instruments which are used to navigate an aircraft on domestic federal airways are of interest to electrical engineers. The ideas used in the design of these compact, direct-reading, accurate instruments are applicable to other fields (*pages 384–88*).

The Importance of Graduate Work in the Power Field. The power field has become so complex that a 4-year college program in engineering is no longer adequate. Graduate work or industrial training programs are essential if the young engineers are going to be able to solve the problems of the present and the future (*pages 391–93*).

Further Development of Fluid Mappers. By this article, those who are building fluid mappers for teaching, research, or application are assisted in understanding the limitations and in minimizing inherent effects tending to reduce accuracy. The numerous problems and needs described should invite interested workers—especially graduate students—to tackle the tasks that will lead to better techniques, a broadening of the range of work to which mappers may be applied, and an increase in the knowledge required for designing fluid mappers for specific jobs (*pages 396–401*).

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Automatic Teletypewriter System. Important features of the full automatic private line teletypewriter switching system are the arrangements provided to permit efficient use of long, full duplex transmission lines, the fully automatic handling o multiple-address messages with only a single originating transmission, and the various guards and alarms which are provided to protect against loss of messages in case of trouble (*pages 408–13*).

Magnetic Alloy with Rectangular Hysteresis Loop. The production of a material in which there is an almost complete flux reversal at a field strength almost equal to the coercive force is accomplished in many ways. A study of the method of obtaining this characteristic by means of heat treatments in a magnetic field is given this month (*pages 420–27*).

Lead-Alloy Power Cable Sheath. Recently developed arsenical-lead alloys for sheathing of underground cable have been found in laboratory tests to have better properties in many respects than does commercially pure lead sheath. Beside being able to withstand bending, internal pressures, and tensile strength, the new material stands up better under the handling involved in installing the cable (*pages 415–20*).

Nuclear and Electronic Magnetic Resonance. Dr. K. K. Darrow of Bell Telephone Laboratories, Inc., presents a discourse on magnetic resonance in matter. Discovery of the phenomenon, which occurred in 1945, has been classed as being as important as Bohr's atom model, Schroedinger's wave mechanics, and the discovery of fission (*pages 401–04*).

Electric Railway System. A method of calculating the losses in a d-c supply system for an electric railway has been developed. It was correlated with a measured value of losses and the data were extended to determine the relative merits of proposed feeder changes and rectifier installations on the Providence, R.I., system. It is believed that this is the first published study that has made use of available probability methods for calculating losses, voltage drop, flicker, and capacity requirements for this type of system (*pages 425–31*).

Mechanical Differential Analyzers. In order that engineers may know more about the capabilities and limitations of one type of computer, an analysis of mechanical differential analyzers and their application to electrical engineering problems is presented this month. Topics discussed are magnetic amplifiers, pulse transformers, and particle trajectories (*pages 432–35*).

Power Interruption Testing of Lightning Arresters. In evaluating tests of lightning arresters care must be taken to record voltages and currents very accurately. Measuring instrument characteristics and locations both affect results, and these effects must be taken into account (*pages 443–47*).

Resharpening the Recording Styli. A method for resharpening a recording stylus by the use of a sodium hydroxide solvent has led to a study of the burnishing facets of the stylus. The polishing action of the burnishing facet results in the groove wall being smooth and free of noise (*pages 447–50*).

An Electromechanical Transducer. At present, transmission techniques have achieved levels of precision not attainable by the common proportional output transducer. A null-balance transducer which can overcome this deficiency is described this month (*pages 437–40*).

Engineering Must Have Prestige. If public appreciation of the engineering profession is to be stimulated, every engineer must publicize his work and the work of his professional colleagues (*page 407*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General
Nov '50, p 44A	Middle Eastern District Fall General
Mar '51, p 35A	Winter General

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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May 1951, Vol. 70, No. 5. Number of copies of this issue 54,400

It is used for carrying cooling water to water-cooled vacuum tubes in radio transmission and other heavy-current electronics circuits.

You are not likely to buy such a water coil. Indeed, you may never see one. Yet if you buy or use electrical equipment which incorporates electrical porcelain, you should be interested in the skills of a porcelain-maker who can produce pieces of such critical difficulty as this.

The story goes back to 1929, when radio engineers asked for a porcelain water coil as an improvement over the rubber hose being used which introduced serious difficulties. We viewed the proposal (as would any producer of electrical porcelain) as highly impractical. Yet by 1932, our engineers had developed a satisfactory method for production of these coils. Since then, many thousands have been made, production reaching a high peak for an extremely critical World War II requirement. So far as we are aware, nowhere else in the world is this product manufactured. It requires a uniformity of clay production, a quality of clay, and an understanding of clay handling techniques achieved in few plants.

You will note that this is a twin-hole tube; the cooling water passes through the outside channel on its way to the tube, absorbs the excess heat, and passes back through the inside channel to the cooling and recirculating pumps. The porcelain is produced by extrusion through dies and "wound" on a cylindrical form. A single coil, after firing, may be as much as 35 ft. long. The coil is glazed inside and out, and during firing, the glaze seals the turns together to form a single rigid piece.

We have a large measure of pride in the accomplishment of production of these coils. It is an accomplishment made possible by skills, techniques and controls which are available to you in porcelain of highest quality for your system. In high-voltage insulators. In porcelain on other equipment. Look for the name LAPP on porcelain for your system. It's a guarantee of sound mechanical and electrical performance, of long life, of low upkeep. Lapp Insulator Co., Inc., LeRoy, N.Y.

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NEW JOINT REINFORCING SLEEVE

OKOMETAL TAPERED LEAD REINFORCEMENT USED IN GARRISON JOINT

TRIPLES LIFE OF POWER CABLES

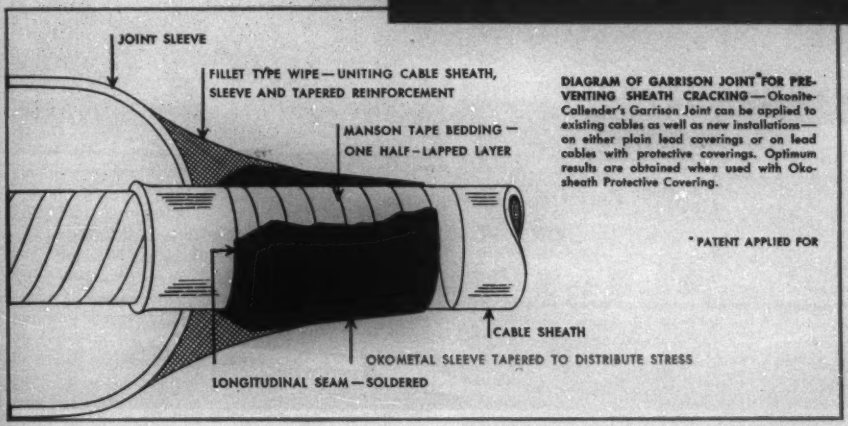
JOINT SLEEVE
FILLET TYPE WIPE—UNITING CABLE SHEATH, SLEEVE AND TAPERED REINFORCEMENT
MANSON TAPE BEDDING—ONE HALF-LAPPED LAYER
CABLE SHEATH
OKOMETAL SLEEVE TAPERED TO DISTRIBUTE STRESS
LONGITUDINAL SEAM—SOLDERED

DIAGRAM OF GARRISON JOINT* FOR PREVENTING SHEATH CRACKING — Okonite-Callender's Garrison Joint can be applied to existing cables as well as new installations—on either plain lead coverings or on lead cables with protective coverings. Optimum results are obtained when used with Okosheath Protective Covering.

* PATENT APPLIED FOR

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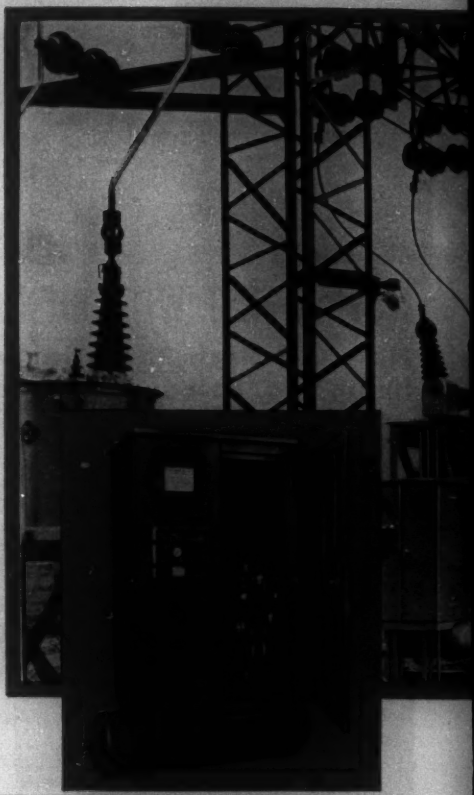
Call your Allis-Chalmers district office for more information on power oil circuit breakers. Or write Allis-Chalmers, Milwaukee 1, Wis., for your copy of the mechanically trip-free pneumatic operator bulletin. A-3355



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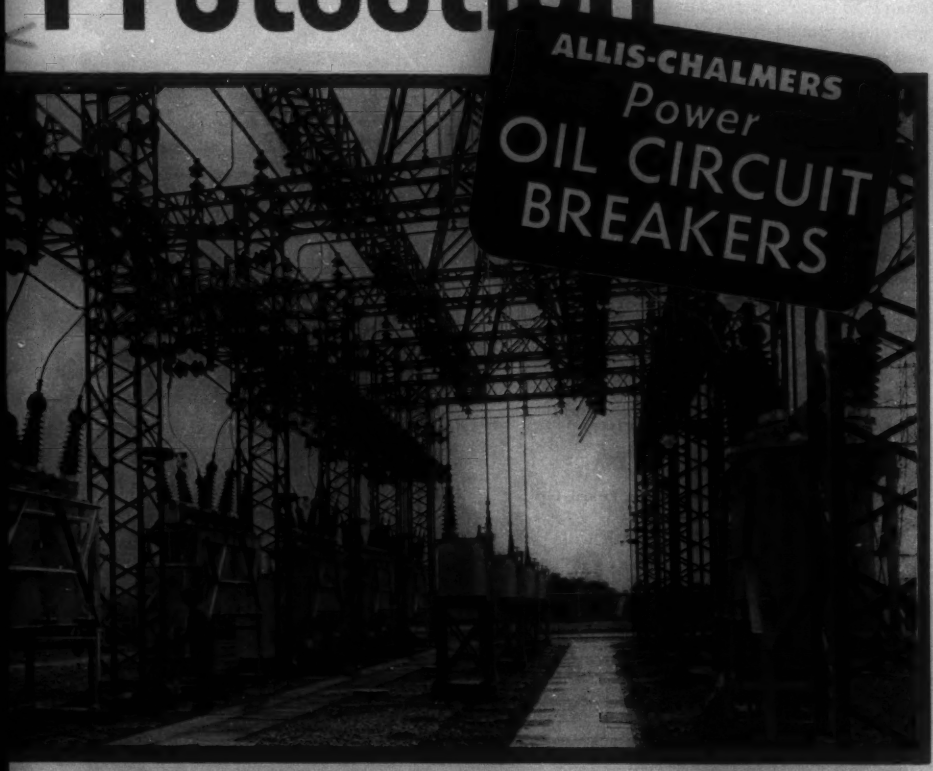

These FZO-151 circuit breakers are equipped with the reliable mechanically trip-free pneumatic operator. The *Ruptor* interrupting device and many other important features also contribute to your assurance of positive operation. The FZO-151 is rated 69 kv up to 3,500,000 kva with 8 to 5 cycle opening, 20 cycle reclosing.

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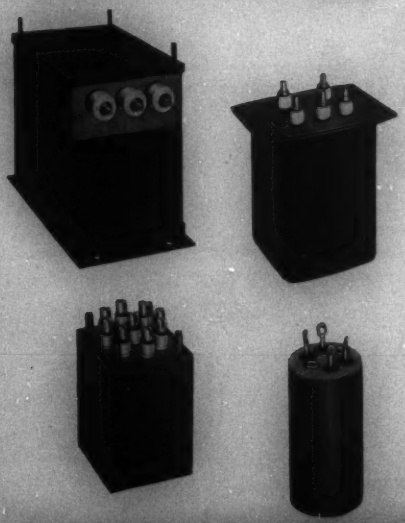

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There is No Finer Name in Transformers than FERRANTI

What Can We Do About the Shortage of Engineers?

T. G. LeCLAIR
PRESIDENT AIEE

IN THE DAYS of Neanderthal man, before recorded history, there was no need for the profession of engineering. Every man killed his own food and fought his own battles. The growth of civilization has brought an increasing need for more and better engineers to promote the progress of the world. If we are to have continued progress, the growth and stature of engineers and the engineering profession must continue.

Do we have a shortage of engineers? If so, why and what are we going to do about it? Two stories appeared in *Electrical Engineering* in February 1951, which point very sharply toward the coming shortage of trained engineers. The story by S. C. Hollister,[1] Dean of Engineering at Cornell University, and the one by the author[2] both point out that the large numbers of engineers graduated in 1949 and 1950 were practically all absorbed in industry, but that the future trend appears to indicate that instead of an annual graduating class of nearly 50,000 men, this number may be reduced to something like 15,000 by 1954. Both of these stories furnish food for thought on the basic shortage which appears to face the country.

Expanding the facilities of technical institutes, training men on the job for specific semiengineering and engineering work, and shifting engineers engaged in nonengineering activities to jobs in their specialty are the three ways President LeClair suggests for overcoming the shortage of engineers in industry and the armed forces.

ARMED FORCES VERSUS CIVILIAN NEEDS

THE APPARENT shortage is made more serious because many of the young men getting out of college may never have an opportunity to be available to industry. The picture, of course, changes from day to day, but as this story went to press there were indications that many young men getting out of college would be inducted immediately into the armed forces without it being determined whether they were more necessary to industry or to the armed forces. Furthermore, there is a serious problem of how young men getting out of high school can be encouraged to carry on and get a technical education. With the drafting of 18-year olds, which in effect means high-school graduates, there is a serious problem of what to do to get the proper number of young men into colleges. This problem becomes difficult because of the fundamental sentiment that no one group of persons should be exempted from draft when others are required to go into military training. This basic philosophy is in keeping with the American practice of equal opportunities and equal requirements for all people. Nevertheless, something must be done for the benefit of the country to get the right kind of men to go into technical training in order that the country can continue to expand and keep its place in competition with other nations who are maintaining a continuous flow of technically trained young men.

MEETING THE SHORTAGE

WITHOUT ATTEMPTING to solve the basic conflict between the needs of the military and of direct employment in industry, let us look at some of the fundamental things which can be done to overcome the shortage of engineers in both fields. The following approaches to this very important problem are worthy of some consideration.

First, it seems desirable to expand the facilities of technical institutes. These schools can train men, and in many cases women, to do highly specialized work of an engineering nature in far less time than the normal 4-year engineering college course. These trained technicians can replace engineers who are now delegated to specialized work, and in all probability a more satisfactory condition would result all around. As a specific example, an engineer with a master's degree who spends all of his time testing insulating oil is wasting his talents. A technician could do this job just as well, and the talents of the trained engineers could be channeled into more productive work.

A second constructive approach is to train men on the job for specific semiengineering and engineering work. A bright high-school graduate can be trained to do certain specialized tasks of an engineering nature without the necessity of having the broader engineering background. Naturally his usefulness would be limited, but nevertheless he could function satisfactorily in an organization with proper supervision. In fact, he might even do a better job in a specialized task than the engineer if the on-the-job training is properly handled.

There is a third fertile source for engineers which can be tapped if necessary. That is, each of us, civilian or military, should look in our own organizations to find those persons who are needed in engineering jobs but who are presently engaged in something entirely different. Sometimes, by shifting activities, a man may be put into work for which he is adequately suited but which someone else

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could also do, and now that the shortage has become acute it would be better to go through that training period to take him out of the nonengineering job and move him into one which will better use that engineering talent. This might be particularly true of some young men who may have taken a job not quite to their liking when there was a rumor that there were more engineers available than jobs. Two or three instances have been brought to my attention where in the military good engineers were available doing nonengineering jobs at the same time that the military were looking for engineers on the outside. I am reminded of an incident of an engineering graduate who did not find a job immediately after graduating from school. In order to make a living, he went back to his father's farm and assumed the duties of a farmer. Naturally he was isolated from engineering societies and contacts with others in the engineering field. As a result, after three years on the farm he was completely unaware of the need for engineers and had no idea as to where to find a job which could use his specialized training.

T. G. LeClair

After we have tapped all the present sources to obtain engineers for the coming increased needs, what can we do to maintain a continuing supply? This is a very difficult problem in connection with the needs of the armed forces, and in connection with the reasonable requirements for universal military service. Both civilians and the military need competent men and they will continue to need competent men in the future. It is necessary to maintain a reasonably continuous flow of technically trained personnel through the normal training channels. It is not too important whether such schooling is obtained under the tutelage of the military or civilian. There may be some difference in the type and speed of training if a man is to be trained while in the armed forces or if he is to be trained as an individual free of any military restrictions; nevertheless, the end goal is just the same.

If we are to have universal military service, and this seemed to be the case at the time this story was going to press, every young high-school graduate must expect to put on a uniform, and he certainly must expect to be subject to rigid military discipline. Can we not work out some scheme under the universal military service whereby in addition to training some men for the various branches of the service we also give to some others a fundamental schooling in engineering? This may be combined with the proper degree of military drill, with barracks life, and all of the other disciplinary needs which are a necessary part of universal service. Through the Reserve Officers Training Corps or through any other suitable means, we should be able to permit a young man to devote a substantial part of his time to his continued education, provided that he meets acceptable scholarship standards. If and when the need for military service ends, these young men may continue their schooling as civilians if they wish.

ENGINEERING MANPOWER COMMISSION

To assist in solving the shortage problem, the Engineering Manpower Commission was formed as a subsidiary of the Engineers Joint Council. The newly elected Chairman of this Commission is Mr. Carey H. Brown, Eastman Kodak Company, who has served on the Commission since its creation, and the other members of the Commission are all very prominent men in industry and in education. The Commission has been called into consultation by the Armed Services Committee of the Senate, by the Selective Services, and by the Department of Defense. The Commission also has prepared material to be given to all high-school principals and many of the high-school instructors to use in advising their students on the value of an engineering education. This is only the beginning of their assignment, and it is expected that they will continue to provide valuable leadership in facing not only the question of the shortage of men but the means by which the needs of industry and the needs of the armed services can be co-ordinated to the better advantage of the whole country.

CONCLUSION

Whatever methods we may use to meet the present problem, it is important that no matter who we are we should not dissipate our time and our talents. The one commodity which is never recoverable is time. If the time of a constructively minded engineer who might be carrying out productive work is permitted to be idle in an unnecessary post, there has been an irrecoverable loss. The burden of work is increasing and we must use our time more efficiently. If we are to maintain our present world leadership not only in civilian pursuits but also in our military activities, we must have sufficient engineering man power.

All of us as engineers and as citizens should give thought to the means of making engineers more plentiful and more useful. It may appear to be a broad problem, but each of us can be of assistance by seeing, in the way that engineers are used in our own daily work, that the shortage is solved and that engineers are made available in the future for more and better jobs and for broader pursuits.

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The Genesis of Submarine Cables

Drawing by R. Dudley

From The Atlantic Telegraph by W. H. Russell

LLOYD ESPENSCHIED

FELLOW AIEE

It was a century ago that the first submarine cable was laid between Dover and Calais. To mark this centenary the author reviews some of the events leading up to this achievement which made possible further advances in the communications field, such as laying of the transatlantic cable by the *Great Eastern* escorted by four ships, as shown in the picture above.

GREAT NEW developments are made possible in the first place through physical discovery and are carried to reality through human enterprise. These creative forces in man are ever with us and stand ready to operate anew. A recalling of their appearance and interplay in the birth of the submarine cable, now a century ago, is appropriate upon this centenary. It is not only interesting history but affords a perspective that is significant today and perhaps suggestive of the future.

Our modern electrical age may be said to have begun two centuries ago, in the 1740's. It was then that man first generated powerful electrical effects, sufficiently so to "shock" himself into a wholesome respect for the mysterious force and an intense interest in its possibilities. In a picturesque period little known to us today, electrical experimentation became a great indoor sport of the courts and learned societies of Europe, and news of it appeared in the magazines, constituting a wave of interest similar to modern radio and electronics.

One of the experimenters was a professor of Greek and Latin of Leipzig, Germany, Johann Heinrich Winkler. He wrote three books, the third upon the discovery of the Leyden jar, dated 1746. Then, probably in 1750, he drafted a comprehensive unifying outline of electrical knowledge, saying, in a section on possible applications: "By means of electricity an effect can be produced, such as the firing of a gun or the giving of a signal, at any given time, at a distance as great as one can ask for on earth."[1]

This is the earliest reference to electric transmission the writer has found in the literature. Note the idea of immediacy, the spanning of distances as great as the earth affords, anticipating, as it were, the submarine cable.

Many must have been the ensuing attempts at realizing this dream; the more outstanding we know from the literature. All were doomed to disappointment. The kind of electricity then available was of an impractically high tension; there just was not the right "impedance fit" for practical use.

DAWN

THE DAWN of the electrical age lasted about a century. Daylight emerged with the discovery of a new form of electricity, that of the galvanic cell and electromagnetic

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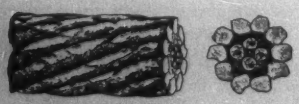
mechanical actuation. This more manageable form of electrical technique assumed practical form in the 1830's, accompanied by rapid invention and the appearance of the electromagnetic telegraph in the forms of: Gauss and Weber with their magneto-induced pulse transmitter and sensitive mirror-galvanometer receiver; Stenheil with his use of ground-return; Wheatstone and Cooke with their dancing needles; Morse with his simple and practical recorder that turned into a sounder.[2]

Invention arises from an intermodulation of technical knowledge and human incentive, a feeling of worthwhileness, a circumstance of appropriateness. By the time technical advances made feasible the electric telegraph, starting in the 1830's, interest in telegraphy had risen apace on the Continent, in the form of the optical relay system that had been known in one form or another since the ancients and had received new development through the invention of the telescope.[3] Under the military urge of the French Revolution and the Napoleonic Wars, the Claude Chappe system of semaphore relay had received a great development in France.[4] Morse tells us that by the 1840's such relay chains extended from Paris to the frontiers of France, totalling some 1,400 miles. In fact, what gave Morse the incentive to advance his form of electromagnetic telegraph was the proposal on the part of the United States Government to establish a visual telegraph chain along the eastern seaboard of North America.[5] What made the electric telegraph a success as of the 1840's was this conjunction of the revived optical telegraph, which left much to be desired, with the promising new electromagnetic technique. A further fortunate conjunction at the time was with the building of railroads which needed telegraphy, and in turn could provide rights-of-way.

The optical telegraph stations of Europe had been erected on promontories and towers where they were removed and protected from the populace. Probably it was this situation and the general state of unrest then existing in Europe that occasioned this state of mind concerning the introduction of the electric telegraph: "It was then regarded as altogether out of the question that a telegraph wire easy of access, attached to posts, could be really serviceable, since it was imagined the public would destroy it. Accordingly, wherever on the European continent it was desired to introduce electrical telegraphs, experiments were first made with subterranean conductors. The best known were those of Professor Jacobi in St. Petersburg. He had tried resin, glass-tubes, and Indian rubber as insulators, but had obtained no permanently satisfactory results."[6] We have this from the man who pioneered the introduction of the telegraph in Germany for the Prussian State in the 1840's, Werner Siemens, who founded the famous electrical firm of Siemens and Halske. The first telegraph line in the United States, that of Morse between Baltimore and Washington, likewise was started on an underground basis. But this proved to be so difficult as to quickly lead to the overhead wires[7] which characterized telegraph development in this country, where the distances were great and the highways were hardly more than ruts through the forest.



From Submarine Cables by Charles Bright

Figure 1. Piece of channel cable laid between Dover and Calais in 1851

MANNA FROM MALAY

REMARKABLE it is that at this juncture, in the 1840's, there came to Europe from Malay a much needed insulating material, gutta percha. It might have been introduced earlier had the Europeans been interested in such a thing, for it seems the material had been in England as early as the middle 1600's.[8] What caused it to attract attention was the readiness with which it could be molded upon being heated to the temperature of hot water, as distinct from India rubber which retained its stiffness and elasticity. William Siemens, then living in London, sent a sample to his brother Werner in Berlin[9] who later wrote of it: "The remarkable properties of this material, of becoming plastic in the heated state, and when cooled being a good insulator of electricity, aroused my attention."[10]

Werner Siemens covered pieces of wire with the heated material, found they were thoroughly insulated, and then devised a screw press whereby the plastic could be cohesively pressed around the copper wires in a continuous process. The first introduction to salt water of gutta percha insulated wire occurred in 1847 when Siemens laid a submarine mine in the harbor of Kiel that was to be electrically detonated from the shore. A gutta percha insulated telegraph line was laid underground from Berlin starting in 1847, and in the following two years extended to Frankfort along a new railroad.[11]

In England electric telegraph exploitation, by Wheatstone and Cooke, started as early as 1838, applied to the railroads, using both underground and overhead construction.[12] Gutta percha had been made into bottles and tubes in 1846; in 1848 Faraday called attention to it as an insulating material;[8,9] and upon the realization of the pressure-extruding process it was put to work for telegraphy to become the foundation of the submarine cable.

COASTAL SUBMARINE CABLES

THE GUTTA PERCHA insulated line was to get its first baptism as a telegraph cable in 1850, in a bold attempt, led by Joseph Brett, to span the English Channel between Dover and Calais. It was a single wire, gutta percha enveloped, with no outer protection. The cable failed almost immediately; but the ability to produce and lay it had been demonstrated and the need of better mechanical protection had been proved.

The project was renewed the following year, this time with a cable of four conductors individually insulated and layed up together. Aid had now been sought of another industry, that of wire-rope making for coal mines. The group of insulated conductors was embedded in the center of a wire rope. This, the first armored cable, was successfully laid and marked the beginning of the submarine telegraph, the Dover-Calais Cable of 1851, the centennial

of which is being commemorated this year[13] (see Figure 1).

It is at the onset of a new development that the imagination runs highest, before minds get set in a new groove. In a book by Edward Highton on "The Electric Telegraph," published the following year, 1852, appear some curious echoes of these first attempts at extending electrical paths through the sea. The author opines that upon our learning how electric fish project their bolts into the sea, there may be "discovered a means of constructing submarine telegraphs without any insulation of the wires: and who shall say whether such a discovery would not satisfactorily solve the problem of communicating instantly between Great Britain and America."[14] The same book, under a section captioned "Telegraphing Without Insulation," recalls that: "Various experiments have been tried in England, America, and India, with a view to ascertaining whether it was possible to send telegraphic communications with naked wires, or even without any wires at all."[15]

No sooner had a new insulating material become available than inventors were trying to eliminate it, and even the conductor itself. Truly, inventors are ungrateful. A foreshadowing of radio, or what?

In the ensuing years additional shallow-water cables were undertaken along the European shores, with the usual alternation of failure and success. Experience accumulated, improvements mounted in the manufacture and testing of the cables, in the handling and laying of them, experience that extended to deep-water cables in the Mediterranean; all the pain and joy of the birth of a new art.

ATLANTIC CABLES

By 1856 the European telegraph network had grown westward to Ireland, the North American network eastward to Newfoundland. The challenge of bridging the great barrier of the North Atlantic was soon accepted by daring spirits on both sides of the Atlantic, notably Cyrus W. Field and John W. Brett, who joined in common enterprise.[16]

The first undertaking was in 1856–57. The cable was to follow a route sounded between Valentia, Ireland, and Trinity Bay, Newfoundland. The manufacture and testing of the 2,000-odd miles of cable, the paying of it out into the depths of the Atlantic from heaving ships, the detecting of the received signals rendered microscopic over that great distance—all constituted the greatest problem yet undertaken in the embryo electrical age. The laying of the cable started from the Valentia end. When deep water was encountered, the paying-out machinery proved inadequate; the preparations had been too rushed. The operation had to be suspended pending improvements and the acquiring of more cable.

Undaunted, the expedition started out anew the following year, employing the same vessels: *H.M.S. Agamemnon* (see Figure 2) and the United States steam frigate *Niagara*. This time they started paying out cable in opposite directions from a splice in mid-Atlantic. There were troubles, but finally the laying was completed. Congratulatory messages flashed back and forth, heraldcd on both sides of the Atlantic; jubilation reigned;[17] literature was full of

Drawing by R. Dudley — From The Atlantic Telegraph by W. H. Russell

Figure 2. *H. M. S. Agamemnon* laying the Atlantic telegraph cable in 1858. A whale crosses the line

the occasion. A quaint little book[18] appeared in 1858 that set forth in verse the entire history of electrical discovery from the time of the Greeks, in terms of the experiences of the Sprite "Electron." In it the author had anticipated:

> "Soon shall Electron glide beneath the Sea,
> Betwixt two worlds, their messenger to be!"

The poem bears the prophetic title *Electron*, and the name of the imaginative poet-historian: William C. Richard.

But the songs of praise were premature; within a few weeks Jinx Electron glided off the wire into the sea, as the insulation failed. The chagrin of the financial backers can be imagined. For them it was an "all or nothing" adventure, and they proved to draw nothing as the cable of 1858 lay silenced and abandoned. About the same time there had been undertaken, in sections, a cable from Suez eastward to India, and it, too, ended disastrously.

The British government had assumed financial responsibility in these projects and now became aroused. Through the Board of Trade there was initiated a joint government-industry committee, charged with going into the subject thoroughly, with the aid of such eminent scientists and engineers as Wheatstone, William Thomson, Charles Bright, the two Varleys, and Latimer Clark.[19*] The finding was constructive—assurance was given that cables could be successfully laid and operated, and more rigorous procedures, including testing, were specified. In fact, this co-operative study may be said to have initiated the formulation of our electrical standards and units.[20]

Further experience was had in the 1860's, with cable projects along the road to India (see Figure 3). Meanwhile, in America, the Civil War raged. Competitive American enterprise entered upon an alternative route to Europe, the overland route through Alaska and Siberia, a

*It was Latimer Clark who made the remarkable collection of early electrical books which were purchased by S. S. Wheeler of Crocker-Wheeler and given to the AIEE, presently in the Engineering Societies Library. Its contents are listed and explained in a 2-volume Catalogue of the Wheeler Gift, published by the AIEE, 1909.

From The Electric Telegraph by D. Lardner

Figure 3. Landing the Indo-European Telegraph Cable in the mud at Fao, Persian Gulf

project that was actually started but dropped when the Atlantic cable materialized.[21]

Some years lapsed before the courageous pioneers of the Atlantic Telegraph again rose to the challenge, but in 1865 the project was renewed. The cable laying was done this time by the famous *Great Eastern*. She started paying out cable from Valentia westward toward Trinity Bay (see Figures 4, 5). Difficulties were encountered, but the laying went on, up to two-thirds of the way. Then, in the course of picking up injured portions to make repair, the cable was lost, including a great length of grappling rope. The expedition returned—"shattered in hopes as well as in ropes," as Bright tells us.[22]

The following year the attack was renewed. Such persistance in the face of adversity is worthy of a rugged age and a great objective. Victory at last; two-fold victory because the cable of the previous year was picked up and completed also (see Figure 6). So 1866 goes down in the book of cable genesis as witnessing "the great feat of the century" as Morse called it: the joining of Europe and America.

THE UNDERLYING ELECTRICAL PROBLEM

Behind the pioneering projects outlined here and continuing down to today and into the future is the fundamental problem of electric transmission; that of the toll taken in energy and time delay, in projecting electromagnetic waves to great distances. The progress made in meeting this basic problem now is traced briefly.

The fact that a well-insulated cable, open at the far end, would "soak up," and in turn discharge, an electric current, was observed by Siemens in 1847 in the course of testing his original gutta percha insulated underground lines.[23] The effect of this electrostatic induction in slowing up the signalling had been not too severe in the shorter coastal cables, but had raised grave doubts as to working across the Atlantic. Experiments on underground wires in England on lengths upward of 2,000 miles showed that dots could be transmitted at the rate of about four per second.[24] This was thought to answer the initial commercial requirement, and the undertaking of the Atlantic cable had followed. The trailing effect of the signals was curtailed by sending dots of opposite polarity alternately; this practice characterizes ocean cable telegraphy.

Following the failure of the first Atlantic cable of 1858, additional experience obtained in the manufacture and testing of cables in England rapidly fortified the insulation situation. The proportioning of the cable as to diameter of conductor and of insulation in respect to speed of signalling came under study and took on the semblance of engineering. Through the contributions of the two Varleys and of William Thomson, it became recognized that the resistance as well as the capacity of the cable affected transmission. Since the speed of signalling was proportional, inversely, to each of these constants, and since each increases with the length of the cable, the speed of signalling was recognized to diminish as the square of the distance. This adverse law called for careful scrutiny of the cable dimensions and constants, and the next attempt at the transatlantic problem was to have the benefit of this engineering knowledge. Thus was born the famous KR Law (capacity times resistance) as a measure, inversely, of the speed of signalling,[25] the forerunner of the more complete propagation law (which includes series inductance and shunt leakage) that was to be appreciated in the age of telephony.

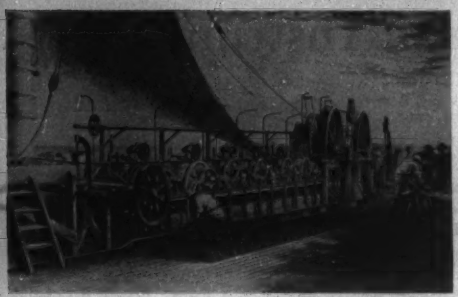
APPARATUS AND EVOLUTION

There were two principal features in the apparatus employed for working these early cables: special keys for sending the plus and minus current pulses; and the use of the reflecting galvanometer, originally employed in the Gauss and Weber telegraph, improved by Helmholtz, and developed in highly sensitive form by William Thomson, later Lord Kelvin.[26,27] The spark recorder followed and then the syphon recorder. Ocean cable reception from the beginning was a matter of eye reading of the sinuous feeble wave. Through the century we have had the submarine cable. So great have been the advances that we cannot do justice to them all, but we might recall;

1. Interest in, and an exploring of, earth currents.

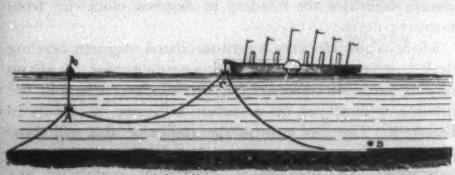
Drawing by R. Dudley — From The Atlantic Telegraph by W. H. Russell

Figure 4. Interior of one of the tanks on board the *Great Eastern*. Cable is being passed above to the deck



Drawing by R. Dudley — From The Atlantic Telegraph by W. H. Russell

Figure 5. Paying-out machinery on deck of the *Great Eastern*



From The Electric Telegraph by D. Lardner

Figure 6. Diagram showing final arrangement for picking up cable of 1865. (A) Point where cable was buoyed to the east by the *Great Eastern*. (B) Point where cable was broken by the *Medway*. (C) Bight of cable brought to surface

2. Reduction of earth-current effects, and a favoring of the higher frequency components of the signal wave, by the use at the terminals of capacitors or transformers—a sort of d-c carrier suppression and equalizing action.

3. Improving transmission by increasing the series inductance, that is, loading.

4. The long series of attempts at amplifying and repeating, ending in the electron amplifier.

Curiously, an enterprising American in 1865 advanced the idea of submerged repeaters, sealed in bombshell-like containers inserted in the cable.[28] But a long-life non-adjustable repeater was missing.

"RETRO-PROSPECT"

THE ESTABLISHMENT of the Atlantic Telegraph concluded the pioneering stage of the submarine cable. Yet in a broader sense the pioneering continues down to the present time, as is seen in the radical departure described in a companion paper,[29] of including electron tube repeaters within the armor of the cable of the new Key West-Havana telephone cable system.

The underlying trend of advance has been one of widening the transmission band and increasing the rate of signalling, thanks to loading in the first place and, more recently, to the vacuum-tube amplifier. Long before the amplifier, in the 1890's, Tesla dreamed in vain of a trans-atlantic telephone cable.[30,31] Today we know the Atlantic telephone cable can be realized.[32] It is a matter of economics, especially in comparison with radio. Meanwhile the art progresses; multichannel carrier working expands. Even more remains to be accomplished, for the sense of sight demands to be transmitted across the seas in this age of television, and the bottom of the sea is well removed from the earth's surface turmoil.

It took a century to realize the electric telegraph and submarine cable. We have had a century of use and advance. What has the third century in store for us, now that the magic Jinx Electron is fully loosed embraced with electromagnetic waves? Surely the Book of Genesis still lies open. Future history may well record that the full Genesis of electric communications, under as well as over the sea, took three centuries.

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Aircraft Navigation Instruments

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Many of the instruments which are used by aircraft navigators are described here. These instruments are designed to be direct reading, unambiguous, and accurate; they must be compact and lightweight, as well as easily seen.

INFORMATION as to the heading and position of an aircraft must be available to the pilot in a usable, continuous, and accurate form. Instrumentation used for navigation by the pilot will be discussed, but no reference will be made to flight, engine, or altitude instruments. Further, no mention will be made of instrumentation used by the navigator on long transoceanic flights.

The instruments required by a pilot to navigate a modern aircraft on domestic federal airways must be direct reading, unambiguous, and accurate. The information available on federal airways now or in the near future requires all or part of the following instruments in the cockpit:

1. Magnetic Heading Indicator.
2. Automatic Direction Finder Indicator.
3. Radio Magnetic Indicator.
4. Omnirange Bearing Selector.
5. Cross Pointer Instrument—includes Deviation Indicator for localizers and omnirange bearings as well as glide path indicator.
6. Omnirange Bearing Indicator.
7. Distance Indicator.
8. Omnimagnetic Instrument—combination of relative magnetic headings, cross pointer, and omnibearing Selector into one instrument.

This article will be confined to a description of the design and operation of these instruments. Reference will be made to the information fed to these instruments only when necessary to explain their operation. All bearings referred to are clockwise from magnetic north.

1. Magnetic Heading Indicator. Although the geographic position of an aircraft may be known by other references, it cannot be flown without reference by the pilot to its heading. Position devices alone do not indicate the direction in which the aircraft is flying; hence, a heading indicator is required. The commonly accepted heading indicator is magnetic and always indicates the heading in degrees, clockwise from magnetic north.

Figure 1. Flux gate remote heading indicator

Modern aircraft carry a gyro-stabilized magnetic heading device, one type of which is the flux gate compass. It has no turning error, is corrected for aircraft deviation, and the heading is displayed on a remote indicator, as shown in Figure 1. The flux gate master indicator also will show heading and combines a number of functions other than indication. An operational schematic explaining the operation of the flux gate system is shown in Figure 2.

2. Automatic Direction Finder Indicator. The standard automatic direction finder (ADF) indicator, Figure 3, usually has two pointers and is arranged so that the arrow head of each pointer points toward the radio station selected for that pointer. The single scale is calibrated from 0 to 360 degrees and can be manually set to the magnetic heading of the aircraft by the pilot.

It contains two repeater synchros, each of which rotates in synchronism with a loop antenna. Its construction is shown in Figure 4, consisting of a hermetically sealed case, rotatable scale, synchros with a pointer on the shaft of each, and a plug for external connections. The shafts of the two synchros are concentric, one being hollow to accommodate the shaft of the rear synchros.

Basically, this indicator furnishes the following information to the pilot, as shown in Figure 5.

1. Relation of station to aircraft, giving a quick visualization of the direction of the station relative to the aircraft heading, since the arrow head of the pointer graphically points to the radio station and relative bearing.
2. Magnetic bearings to or from the aircraft to the station as read at head or tail of the pointer; 250 and 70 degrees respectively, as shown in example in Figure 5.

The advantage of the ADF has always been its simplicity of use in visually indicating the direction of the radio station without mental computation. It is very helpful for orientation on low-frequency radio ranges, establishing a heading on a range beam with cross wind, homing, approach procedures to an airport, and radio fixes. It is standard equipment on all military and multiengine civil aircraft.

Full text of a district paper presented at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950.

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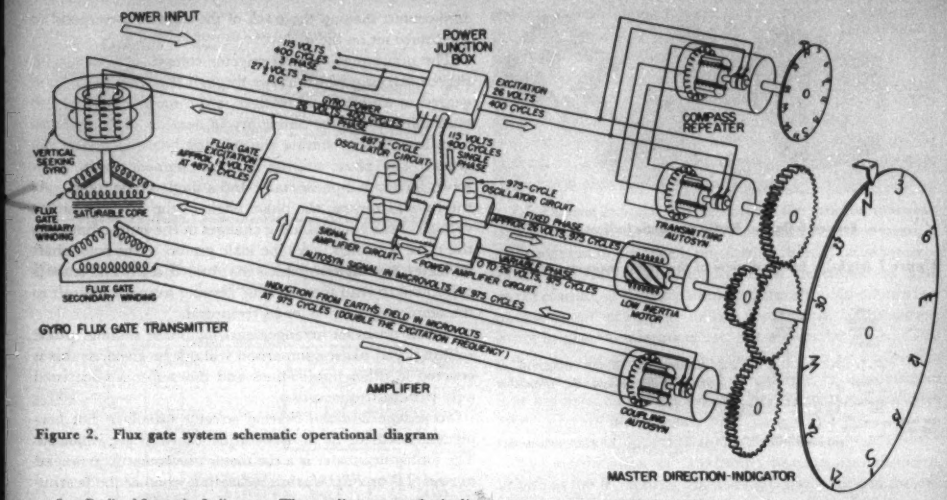
POWER INPUT
POWER JUNCTION BOX
115 VOLTS 400 CYCLES 3 PHASE
27½ VOLTS D.C.
EXCITATION 26 VOLTS 400 CYCLES
GYRO POWER 26 VOLTS 400 CYCLES 3 PHASE
COMPASS REPEATER
VERTICAL SEEKING GYRO
FLUX GATE EXCITATION APPROX. 1½ VOLTS AT 487½ CYCLES
487½-CYCLE OSCILLATOR CIRCUIT
115 VOLTS 400 CYCLES SINGLE PHASE
975-CYCLE OSCILLATOR CIRCUIT
FLUX GATE SATURABLE CORE
FLUX GATE PRIMARY WINDING
FIXED PHASE APPROX. 26 VOLTS 975 CYCLES
TRANSMITTING AUTOSYN
SIGNAL AMPLIFIER CIRCUIT
AUTOSYN SIGNAL IN MICROVOLTS AT 975 CYCLES
VARIABLE PHASE 0 TO 75 VOLTS 975 CYCLES
POWER AMPLIFIER CIRCUIT
LOW INERTIA MOTOR
FLUX GATE SECONDARY WINDING
INDUCTION FROM EARTH'S FIELD IN MICROVOLTS AT 975 CYCLES (DOUBLE THE EXCITATION FREQUENCY)
GYRO FLUX GATE TRANSMITTER
AMPLIFIER
COUPLING AUTOSYN
MASTER DIRECTION-INDICATOR

Figure 2. Flux gate system schematic operational diagram

3. Radio Magnetic Indicator. The radio magnetic indicator (RMI) is similar to the ADF indicator, except that the scale is automatically and continuously rotated to the aircraft heading by remote information from the flux gate magnetic compass. The pointers may be fed information from the ADF as described in the preceding section and point to the station. However, the instrument is more versatile as the magnetic bearing to or from the radio station is available continuously without the necessity for the pilot manually setting the scale to the aircraft heading. The front view, shown in Figure 6, is identical to the ADF indicator in Figure 4, except the knob is removed as it is not needed.

In addition to ADF indication, this instrument is used to convert very-high-frequency omnirange bearings to ADF-type heading sensitive indications by combining heading with omnirange bearing. This is covered in more detail in the section on omnirange indicators.

The construction of the RMI is rather complex as the shafts of three synchros must be concentric at one point. Earlier designs required a servomechanism with a gear train and motor to obtain sufficient torque to position accurately the scale drive to its weight and shaft friction. However, in the latest design, refinement of bearings, low-friction gears, and higher torque synchros have eliminated the servo, and the two pointers and scale are driven directly by synchros. A precision arrangement of low-torque and low-friction bearings and gears allows the synchros to be offset; otherwise, the instrument would become too long and bearings too large in diameter. An internal view in Figure 7 shows this arrangement. The unit is hermetically sealed and filled with dry nitrogen to protect the bearings' lubrication from oxidation and contamination. When it is remembered that only a 2,500-milligram-millimeter torque at 1-degree displace-

Figure 3 (above). Automatic direction finder indicator MN-58

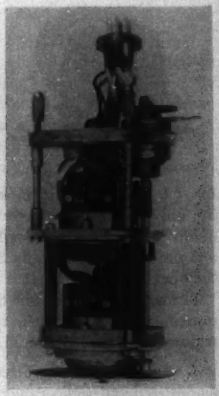

Figure 4 (right). Internal view of the automatic direction finder indicator

Figure 5 (below). Automatic direction finder indication with scale adjusted to heading

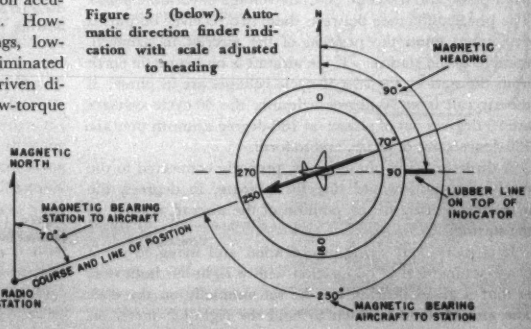

Figure 6 (left). Radio magnetic indicator

Figure 7 (right). Internal view of the radio magnetic indicator

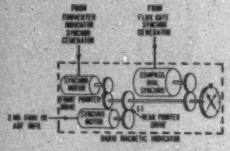

Figure 8. Block diagram of the radio magnetic indicator

Figure 9. Omnibearing selector MN-82

ment is available from these miniature synchros, which are only 1 inch in diameter and $1^1/_8$ inches long, the precision with which the bearings and gears must be made and protected can be realized. A block diagram showing the operation of the RMI is illustrated in Figure 8.

Refinement of design and hermetic sealing has made these instruments very reliable in spite of their delicacy, and they seldom fail in rugged aircraft service.

4. Omnirange Bearing Selector. The very-high-frequency omnidirectional radio range station provides output from an aircraft receiver which consists of a 30-cycle voltage of fixed phase and a second 30-cycle voltage of variable phase. The phase difference between these two receiver outputs is dependent upon the position of the aircraft in azimuth, relative to the station. If the aircraft is on magnetic north from the station, the two 30-cycle voltages are in phase; if the aircraft is at 90-degree azimuth, the 30-cycle voltages are 90 degrees out of phase; at 180-degree azimuth they are 180 degrees out of phase, and so forth.

A direct-reading phase meter, properly connected to the receiver output, would directly indicate, in degrees, the magnetic bearing of the position of the aircraft relative to the station.

It is more convenient in operation and flying to use a phase-setting dial in connection with a right-left indicator, so that a given bearing can be set manually on the dial. The aircraft then is flown to hold the right-left meter on zero-center, making the track of the aircraft correspond to the course set on the dial.

The omnirange bearing selector consists of a tape with degree marking which shows through the window, a knob geared to an electrical resolver, a d-c meter movement to eliminate 180-degree ambiguity in bearing, and a mechanism for quickly shifting the selected bearing by 180 degrees. The phase shifting is done magnetically in a resolver having a 2-phase stator and a single-phase rotor. As the rotor is turned, the phase angle of the 30-cycle output voltage of the rotor winding changes in the same amount as the rotor is turned. A tape scale geared to the rotor shaft indicates the angle to which the rotor is set. The scale is calibrated to read the magnetic bearing from the aircraft to the omnirange station, or its reciprocal.

Details on exact arrangements for phase shifting, phase splitting, and phase comparison will not be given, as this is covered in other publications and this paper is concerned only with instrumentation.

To reduce cost the bearing selector usually is not hermetically sealed, as no low-torque bearings are required. The ambiguity meter is a d-c meter movement so arranged to read *TO* or *FROM*, thus indicating whether the bearing shown in the window is the bearing to or from the station.

A view of the instrument is shown in Figure 9. A block diagram of the bearing selector is shown in Figure 10.

The bearing selector is used in association with the cross pointer indicator.

5. Cross Pointer Indicator ID-48. This instrument is a standard aircraft instrument panel case containing four d-c microammeter movements. One movement operates a vertical pointer for use with the omnibearing selector for flying omnirange courses and instrument landing localizer courses. A second movement operates a horizontal pointer for maintaining the aircraft on a glide path during an instrument approach to a runway on instrument landing system. The other two movements operate red flags associated with each of the pointers to indicate malfunctioning of either system. All movements are on the order of 150

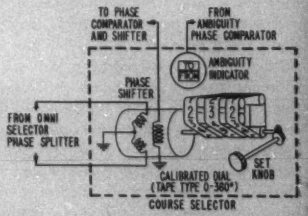

Figure 10. Block diagram of the omnibearing selector MN-82

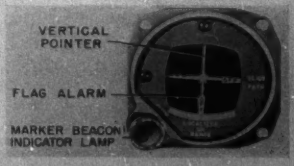

Figure 11. Cross pointer indicator ID-48

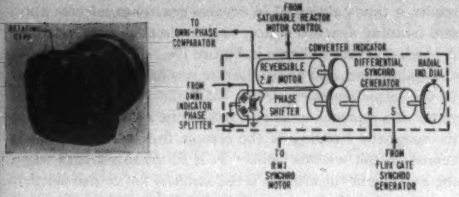

Figure 12 (left). Omnibearing converter-indicator

Figure 13 (right). Block diagram of the omnibearing converter-indicator

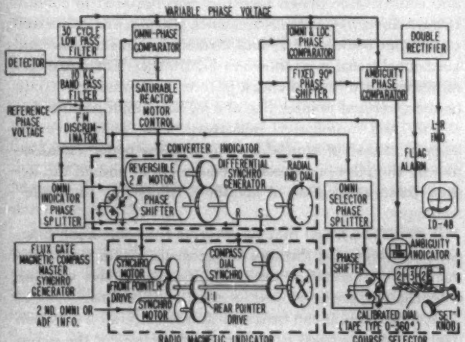

Figure 14. Block diagram of automatic phase instruments

microamperes for full scales. The instrument has been designed to withstand rugged aircraft service and is standard in all large aircraft. A view is shown in Figure 11.

6. Omnibearing Converter Indicator. Although this instrument is seldom used in the cockpit for actual navigation, it is an essential part of the omnirange aircraft equipment to derive automatic bearings for combination with heading to operate the RMI. It consists of a phase shifter, gear drive, differential synchro, and bearing scale on one shaft. A view is shown in Figure 12, and it is diagrammatically shown in Figure 13. The phase shifter operates in the same manner as the omnibearing selector phase shifter, except that the shaft is driven to the actual bearing by a servo deriving its torque from the voltages available when the receiver-output 30-cycle voltages are out of phase. The shaft is positioned automatically by a null occurring when the voltages are in phase. An over-all block diagram showing the receiver output, radial converter-indicator, omnibearing selector, and RMI is shown in Figure 14. A differential synchro, which will take two inputs and add them algebraically, is driven by the omnibearing shaft to add magnetic heading algebraically to the omnibearing. A little thought will show that this will result in relative bearing to feed a pointer on the RMI, thus creating an ADF on a very-high-frequency omnistation. The advantage of a heading sensitive indication such as this is hard to visualize unless you have attempted to orient yourself in an aircraft by a position sensitive indication only, such as the direct reading obtained from the omnibearing converter-indicator. It tells the navigator he is on a definite line of position in space, but does not tell him how he is heading relative to that line of position. He can fly a circle at that position and the bearing indication does not change, but the RMI does change and always points to the station.

7. Distance Indicator. To complete the position information by reference to one geographic point on the ground, a measurement of distance is required. Special pulse interrogator-responder equipment has been developed to give direct reading of distance from the aircraft to an omnirange station or end of runway on one instrument. This system is not in general operation yet, but will be by 1952. The instrument for distance indication is shown in Figure 15. The design is not frozen as yet, but the counter-pointer type has been tentatively selected to prevent confusion with other aircraft instruments, such as an altimeter, and to show the rate of approach to the runway.

The combination of omnirange bearing and distance, known as the *R-θ* system, allows ready application of the offset computer to allow parallel airways of the future to be flown by reference to a single omnirange-distance-measuring-station on the ground.

8. Omnimagnetic Indicator. This instrument combines the cross pointer indicator *ID-48* and the omnibearing selector and is shown in Figure 16. A third relative heading needle has been added to assist in flying an omnirange or localizer course. It was developed for two reasons: (1) to conserve valuable instrument panel space, and (2) to add the vital relative heading to the position needle. It is beyond the scope of this article to go into the necessity of adding relative heading to the position pointer, but it is sufficient to state that it is impossible to fly the aircraft without reference to a heading indicator. This instrument makes it unnecessary to look at a second instrument during a diffi-

Figure 15. Distance-measuring equipment indicator

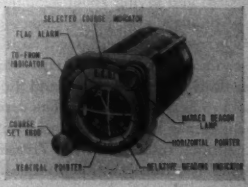

Figure 16. Omnimagnetic indicator

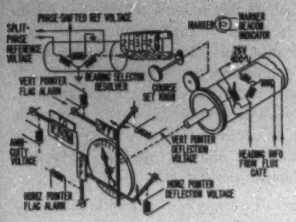

Figure 17. Block diagram of the omnimagnetic indicator

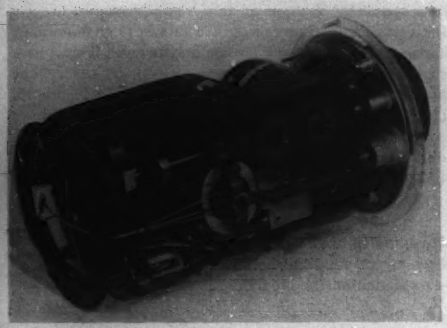

Figure 18. Internal view of the omnimagnetic indicator

cult instrument letdown, and eliminates the necessity for mentally computing different headings as an instrument landing letdown procedure to an airport is executed, as the heading of the aircraft relative to the selected course is always visualized instantly.

The instrument consists of five microammeter movements, a tape calibrated in degrees geared to selector knob and heading synchro stator, and a phase-shifting synchro. A block diagram is shown in Figure 17. The selector knob, calibrated tape, and phase-shifting synchro operate identical to the omnibearing selector *MN*-82. In addition, the stator of a repeater synchro, deriving its rotor position from the magnetic heading of the remote flux gate compass, is geared to the selector knob. It is so arranged that when the heading of the aircraft is the same as the course elected, and the aircraft is on course, the short relative heading pointer will be vertical and aligned with course deviation pointer. If the aircraft is turned right, relative heading pointer will point right; and if the aircraft is turned left, pointer will point left—showing the degrees turned.

This instrument represents the utmost in complexity, and considerable design ingenuity was required to contain two synchros, five meter movements, gearing, and calibrated tape in one standard $3^1/_2$-inch aircraft instrument case and hermetically seal it, as shown in Figure 18. The five meter movements are vertical course pointer, horizontal glide path pointer, vertical pointer flag alarm, horizontal pointer flag alarm, and ambiguity indicator. The pointers move linearly instead of around a pivot to allow better visualization by the pilot of himself at center circle and of the desired paths at location of pointer to allow "fly to needle" technique.

It should be noted that all external rotatable knob functions are connected through the hermetic seal of the instruments by a hermeflex joint. This is a bellows with an eccentric motion developed for such applications.

In conclusion, it can be stated that the aircraft navigation instruments described in this paper do represent the major complement that are or will be used in all airlines and most military aircraft to navigate on federal airways. Some other instruments are in limited use or have been proposed, but it is felt that those described give a composite view of those most generally used.

Electronic Machine Developed for Counting Worn-Out Money

A fully automatic electronic machine for counting worn-out money has been developed by the National Bureau of Standards (NBS) for the Department of the Treasury. The currency counter counts 30,000 notes per hour. Twenty-five of these machines will be placed in service soon by the Treasury, replacing the present hand-count system and saving about $250,000 annually.

Although new paper money has been machine-counted for many years, mechanical handling of worn-out notes has been a problem. About eight tons of currency are turned in daily for redemption, and the notes are wrinkled, limp, and difficult to handle. The variable condition of returned money has required tedious counting by hand.

Money returned to the Treasury is in the form of packets of 100 notes cut longitudinally into half-notes. These stapled packets are placed on an inclined trough and pushed into the machine. The stapled end is grasped by metal jaws and the packet is wrapped tightly around a spindle, spreading the outer edges of the notes against a friction band. As the spindle rotates the notes clear the friction band and are separated by a jet of air.

The counting is achieved by using an electronic sensing device consisting of a beam of light and a phototube system. As the notes unfurl, interrupting the beam of light, the phototube senses the interruptions of the beam. Impulses from the phototube are fed to a binary counter which tallies the individual impulses. The sum of these impulses is used to actuate a sorting vane, automatically rejecting packets if the count is more or less than 100. Except for filling the trough, machines operate unattended.

Die-Cast Rotor Studies

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A MOTOR is no better than its rotor. Therefore, the rotor should receive the same quality control attention as the stator and other elements.

Die-cast rotors have many advantages over the copper-cage rotors for induction motors but they also can have more possible defects, because of the nature of the processing, such as stray load losses, high-resistance or broken bars, wrong die-casting alloy, improper skew of the slots which is difficult to see in closed slot rotors, eccentricity of rotors, and improper thickness of the bridges over closed slot rotors. These faults cause poor performance, and most of these defects can be tested for excessive noise.

These defects can be detected by separate pieces of equipment, both quantitatively and visually. It is desirable to test rotors prior to the final processing of the rotor or final assembly of the motor. High production requires that test equipment shall be simple and quickly operated. Many high quality products require that die-cast rotors be tested for all defects.

Shown in Figure 1 is a front view of the complete test equipment to check all rotor defects quantitatively and visually. The unit consists of a motor driving the rotor to be tested. Surrounding the rotor is a 3-phase test stator. The rotor is driven in a direction opposite to that of the rotating field of the stator. Around one tooth near the center of one pole of one phase of the test stator is wound an exploring coil which is connected to an oscilloscope, shown on the left side of Figure 1. This phase is excited with direct current for visual tests.

An interlocked switch excites the 3-phase stator with alternating current for the stray load loss and other quantitative tests. The d-c circuit is open. Watt readings in the drive motor circuit correlate driving torque with stray load losses. Current readings in the test stator circuit detect high-resistance bars or rings, large number of broken bars, and skew. This test will not detect a small number of broken bars. It is desirable to reject all broken bars from a noise standpoint.

Figure 1. Complete unit for testing die-cast rotors visually and quantitatively

Broken bars and all other defects can be shown visually on the oscilloscope screen by opening the a-c circuit and closing the d-c circuit with rotor revolving. The d-c excitation of one phase produces only a pulsating current resulting from the rotation of the rotor teeth and bars. This in turn sets up a pulsation of the flux in the air gap by bucking down the primary flux. Each tooth or bar passing

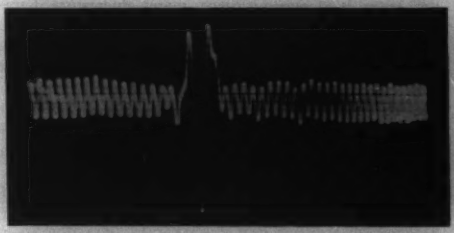

Figure 2. Die-cast rotor with one broken bar designated by high peaked wave

the exploring coil shows on the oscilloscope screen as a sine wave. When the sweep circuit of the oscilloscope is synchronized with the speed of the rotor teeth, a band of sine waves representing all of the rotor bars is shown on the screen.

A good rotor of uniform resistance will have a wave band of uniform height. High-resistance bars will have lower current flowing in them; thus they have less effect in bucking down the primary flux. Therefore, the flux approaches a maximum peak value. Broken bars have no current flowing, therefore the primary flux reaches the maximum peak value, as shown by one broken bar in Figure 2. Stray load losses show up as a high modulated form of wave band. Other defects show up in the height of the wave band.

A synchronizing pulse is used when it is desired to show the location of the defect.

The combined test unit is operated at a rate of approximately 150 rotors per hour. The net result is better with more uniform performance, a more uniform flow of production, and a higher quality end product.

Individual visual test units have been used employing both permanent magnet and electromagnet with a pick-up coil to an oscilloscope and a synchronizing pulse. This type of unit is adaptable to all sizes and types of squirrel-cage motors.

Digest of paper 51-117, "Die Cast Rotor Studies," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Not scheduled for publication in AIEE *Transactions*.

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Noise Evaluation of Fluorescent Lamp Ballasts

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NOISE TESTING of fluorescent lamp ballasts has been studied from a number of approaches. A system has evolved from these studies which, if acceptable to the industry, may provide a basis for industry specifications and standards regarding this type of measurement.

The fluorescent lamp is a gaseous discharge device, and therefore must have an impedance or ballast connected in series to limit the current to the value for which the lamp is designed. Since many fluorescent lamps require starting voltages exceeding normal supply voltage, the ballast may also include a means for transforming the available circuit voltage. For 60-cycle a-c systems, the most efficient device for limiting the current is a reactor, and the usual device for voltage transformation is the transformer or autotransformer. The reactor or autotransformer, like other electromagnetic devices, is a source of audible radiation or noise.

Light sources such as the candle and incandescent lamp have been almost devoid of noise. The user of light, therefore, has not generally considered audible sounds or noise as a necessary component of lighting. The introduction of the fluorescent lamp brought an appreciable increase in noise to lighting of this type, so that the problem of noise reduction became very acute. The primary purpose for developing a noise measurement system was to obtain realistic noise quality numbers which would define the noise characteristics of a fluorescent lamp ballast.

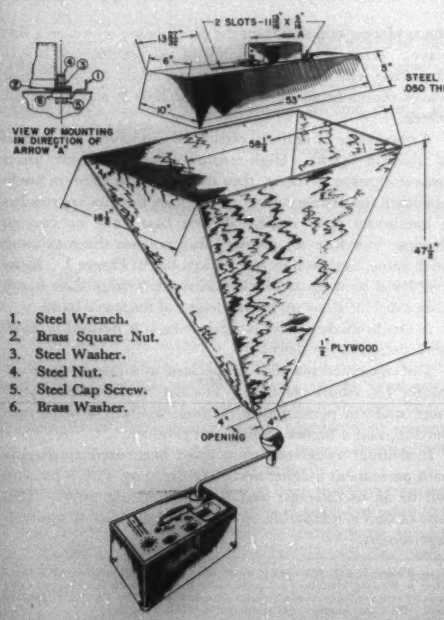

Figure 1. Construction details of the ballast noise test assembly

The early attempts to measure fluorescent lamp ballast noise included ear listening tests, but a sound-level meter was soon employed to determine noise levels. The use of the sound meter provided numbers for ballast noise, but it did not adequately define the characteristics of the ballast as employed in field applications. Extensive noise tests were taken with commercial fixtures which indicated that the fluorescent lamp fixture in which the ballast is mounted must be included in any noise evaluation of the fluorescent lamp ballast. These early studies led to the development of a dummy fluorescent fixture which would respond to the noise generated by the ballast.

Since it was impractical to take a series of readings along the length of the fixture, a horn was fabricated from plywood to collect or concentrate the noise produced by the combination of ballast and fixture. A sound-level meter was incorporated to detect the resultant noise, as shown in Figure 1. With this noise test assembly, the noise generated by the ballast, amplified by the dummy fixture, and collected by the horn, was measured as decibels by the sound-level meter. This noise test combination provided realistic data which would define the noise characteristics of the fluorescent lamp ballast.

Modifications in the noise test assembly have been found necessary to improve test procedures. Several variables have been encountered which must be carefully controlled in this test. These have included ballast mounting on the top surface of the dummy fixture, ballast temperature, and fluorescent lamp operating temperature.

This test equipment, developed to evaluate the noise characteristics of fluorescent lamp ballasts, has had several important applications. It has been a valuable tool in the evaluation of new designs and proposed methods for reducing ballast noise. The test procedure is too lengthy for a 100-per cent production noise test, but it is suitable for quality sampling tests. This measurement system is by no means perfect, and it is hoped that others will try this system so that further improvements may be possible.

Some changes are to be expected, but is felt that this measurement system has been developed far enough to be considered by others who are concerned with the problems of ballast noise and its measurement.

Digest of paper 51-95, "Noise Evaluation of Fluorescent Lamp Ballasts," recommended by the AIEE Committee on Production and Application of Light and approved by the AIEE Technical Program Committee for presentation at the Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Importance of Graduate Work in the Power Field

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Further graduate training, either in the colleges or in formal courses organized as part of industry training programs, are essential if the electrical engineer is to be prepared to meet the present and future problems of the electric power industry.

IT IS the purpose of this article to discuss the education and training of young engineers who enter the electric power industry. Although the field includes many phases of industry and manufacturing, particular attention will be directed to the training of engineers for the public utilities supplying electric power service and for the application groups of the manufacturing companies which supply the equipment needed by the public utilities.

In large measure, the engineering staffs of the public utilities in the United States entered the industry in the decade from 1920 to 1930. Most of these men were college graduates and entered the industry after receiving the bachelor's degree following a 4-year electrical engineering course. On the basis of a normal retirement age of 65 years, which will be prevalent at the time this group retires, these engineers will retire in the period from 1963 to 1973. During the depression years and the years of World War II, the additions of young engineers to these organizations were relatively few in number. With the continuing growth of the power industry, almost complete staff replacements and additions to keep pace with growth must be made so that trained staffs may be prepared to take over the major engineering duties in a few years.

THE ENGINEERING GRADUATE OF 1925

IN CONSIDERING the present engineering group, the education of the electrical engineering graduate of 1925 may be considered as typical. At that time, an educational program of four college years leading to a bachelor's degree was standard, and advanced work leading to a master's or doctor's degree was extremely unusual. The 4-year graduate found himself reasonably well trained for the problems of the power system which he encountered at that period. Although the curriculum at that time was not considered to be specialized, it contained little or no training in electronics and communication or radio, which is an essential part of every electrical engineering curriculum today. Furthermore, the emphasis on the broadening of the outlook of engineering graduates has resulted in increased emphasis on liberal studies and humanities in the curriculum, with resultant decrease in technical content. Thus, in comparison with the 4-year engineering curriculum of today, the curriculum of the graduate of 1925 would be considered a specialized one in the power field. Upon entering the power industry in 1925, the electrical engineer was frequently subjected to a training program of one year or more, conducted by the utility, or by the larger manufacturing companies. These training courses varied greatly, but included studies of the planning, design, and operation of the power systems of that day, and of the apparatus and its characteristics available at that time. Further training was for the most part accomplished by experience on the job, by attendance at technical society meetings, and by self-study.

GROWTH OF TECHNICAL REQUIREMENTS

IN THE YEARS which have intervened, the technical requirements of electric power systems have grown enormously. In 1925, reliable and accurate short-circuit analyses of power-system unbalanced faults were almost unknown. The methods of symmetrical components and similar related components by which these problems are solved regularly today were considered then the tools only of the advanced theorist. The entire technique of lightning protection involving the analyses of impulses and traveling waves, insulation co-ordination, and apparatus protection were unknown. Load and frequency control to a high degree of accuracy were dreams rather than realities. The concept of reactive power and the control of reactive power in voltage regulation was unknown. Protective relaying was confined largely to overcurrent relaying, and high-speed protective relaying was relatively unknown.

It is apparent to anyone familiar with power systems of the present day who has read the brief recital of engineering as viewed in 1925 that tremendous engineering developments have taken place. Although the present engineering staffs have met these developments effectively, and have applied them generally to power systems throughout the country, the necessary knowledge of new developments has been gained the hard way, and is not nearly as widespread or as thorough as it should be for the most effective utilization of engineering developments. Many engineers who could profit by knowledge of these developments have not had the opportunity for training in the advances that have taken place, and must rely on meager knowledge and half truths, and, in many cases, on the copying of practices of other utilities which may or may

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not be most effective for their particular problems. It seems almost self-evident that substantial improvements in power-system planning, design, construction, and operation could be effected if the public utility and manufacturing engineers were fully familiar with the important developments of the intervening years.

The knowledge and techniques applicable to power-system problems which have been developed over the past 25 years and which are continuing to develop at a rapid rate have frequently been given the name "Power-Systems Engineering," a term which is coming into more frequent use daily in the industry, in educational circles, and in engineer recruiting programs. If the young engineer being recruited today is going to be able to solve the power-systems engineering problems of the immediate future, it is essential either that he come equipped with education in this special field or that adequate training programs be set up to provide him with the specialized training and knowledge needed after his entry into the industry.

FUNDAMENTAL EDUCATION

It is as true today as it ever was that the training of an engineer is never complete, and that he must continue to develop as long as he practices the engineering profession, if his work is to be crowned with a full measure of success. This means that the young engineer, as he leaves college, must not consider that his education is complete, but that he must plan to apply himself to the study of technical problems in the future as they are encountered. Thus, the education of the engineer is obtained only partly in college, and must be supplemented on the job throughout his career. The problem which confronts educators and those in industry responsible for personnel recruiting is to determine what part of the education should be completed in college and what part of the training should be developed on the job. It is usually agreed by both groups that the colleges should teach the fundamentals and the applications should be left to industry. However, such a decision does not solve the problem because it is then necessary to decide what is fundamental and what is applied education. The definition of a fundamental subject will differ widely from engineer to engineer, but many an engineer will define as fundamental all of the specialized knowledge needed to solve the technical problems of his present position. As the requirements of technical positions differ so widely, it is of course obvious that the composite fundamentals of all engineers in the public utility business would be beyond the scope of any college curriculum.

Nevertheless, there is a growing conviction that the fundamental preparation for power-systems engineering must include knowledge of some or all of these subjects:

1. The behavior of long transmission lines where the effect of distributed capacitance is important.
2. The basic behavior of impulses and traveling waves.
3. Electric transients in circuits and machines.
4. Symmetrical and related components for the analysis of unbalanced polyphase systems.
5. Power limits and the elements of power-system stability.
6. Basic lightning phenomena.
7. Electric fields and high-voltage phenomena, including corona and radio influence.
8. Principles of protective relaying.

Regardless of whether or not full agreement can be obtained on the preceding list of fundamental topics, it is evident that almost none of them were included in the typical college education of the engineer who graduated 25 years ago. In the curriculum of today some treatment of the first three topics of the list usually is included, but the coverage is limited and often is arranged to stress the effects prominent at the higher frequencies of communication circuits. If the remaining topics are treated at all, they usually must be elected as part of a limited option in power which the larger colleges and universities may offer, but not more than one or two of these topics can be considered, even briefly, without the omission of broader and more fundamental topics usually considered essential in any engineering curriculum. Furthermore, because of the time spent on basic electronics, communication, and radio, which were almost unknown in college curricula 25 years ago, and the increased emphasis on liberal studies, the time available for polyphase circuits and transformers and for rotating machines is almost surely less than it was then. Thus, in some respects, the graduate of today has a less thorough knowledge of topics of basic importance to power systems than his fellow graduate of 25 years ago. On the other hand, he is far better prepared in his knowledge of electronics, communication, and radio, all of which are making important invasions into power-systems engineering than the earlier graduate. In general, he probably has a better knowledge of economics, accounting and finance, public speaking, and the humanities.

FUTURE EDUCATIONAL REQUIREMENTS

This analysis so far has been concerned largely with power-systems engineering as it is today. With the current developments which are taking place at a rapid rate, it is foolish to think that equally important developments will not take place during the next 25 years if the electric power industry is to keep pace with its needs. The engineers entering the industry today must be prepared not only to meet the present problems but to solve the problems of the future by knowledge gained from everyday operations in the industry. Therefore, it becomes increasingly evident that additional training must be supplied to those young graduate engineers who are to fulfill the important places in the power-systems field during the next 10 to 25 years. With the new problems which must be met, it is almost unthinkable that preparation to meet the current problems must be acquired in the same painstaking way it has been acquired in the past.

The alternative, and, for many of the subjects listed, the far more efficient way, is to provide training in organized courses, given either as graduate work in the colleges or as part of graduate training programs in industry. Which of these two alternatives is adopted is not of vital importance. The important thing is that either one or both of these alternatives be adopted and developed to the full. Yet, at the present time, few colleges and universities offer a

graduate training program in the power-systems engineering field encompassing satisfactorily all or most of the more fundamental topics listed previously. On the other hand, rapid growth has taken place in graduate work in electronics, communication, radio, and radar. At the same time, few utility systems have augmented their programs to include effective coverage of these subjects. In general, only the larger utilities are equipped or can afford to develop and offer training programs which are adequate for the needs. Thus, it seems evident that in many cases, if the job is to be done, it must be done by the colleges, in the form of graduate courses, leading perhaps to the master's degree. In big cities evening graduate courses for employed engineers can be used effectively but this will not serve for those employed in the smaller cities.

This leads immediately to the next question: "Why do not the colleges and universities do more about it?" The answer is not simple, but a large part of the answer appears to be the lack of an expressed demand on the part of the public utility industry for graduates with advanced training. The industry is not yet accustomed to seeking any but the 4-year graduate. Yet, if the colleges are to do the job outlined in the foregoing in a satisfactory manner, it is essential that the public utilities and manufacturers, in their own interest, give recognition to the value of the training required by recruiting engineers who have this training and by offering salary inducements which will repay the student for the time and effort spent in obtaining a year or more of specialized training.

Another reason for the lack of adequate graduate programs in the power-systems field is the almost complete absence of sponsored university and college research in the problems of the electric-power industry. The opinion is widely held today that the colleges and universities of the United States must carry on far more fundamental research than ever before, to continue and expand the developments and basic knowledge which, prior to World War II, came largely from Europe. With the devastation of Europe, resulting from the war, progress of fundamental research in Europe has become almost nonexistent. Although the United States has excelled in applied research and development, most of the basic ideas of the past have been imported from Europe, and development to commercial fruition has been made by industry here.

NECESSITY FOR SPONSORED RESEARCH

To provide adequate preparation for the future, expanded and augmented research of a fundamental character must be developed in the United States in an atmosphere free from commercial urgency and sales pressure. In many fields, extensive programs of fundamental research have been developed since World War II with industry, or for the most part government, sponsorship. Tremendous programs in electronics, servomechanisms, radio, television, guided missiles, and other phases of electrical engineering have been developed, and the colleges have participated widely in these programs. On the other hand, little or no sponsorship has been provided by industry, the government, or anyone else, for the support of fundamental research seeking the solutions of problems confronting the power-system industry. Although it may be true that the problems of the industry are less acute and critical than problems in other phases of the electrical industry, there are many problems which are still unsolved. It is also true that many of the problems not solved satisfactorily in the power field involve more critical research by the chemist, metallurgist, or the physicist than research by the orthodox electrical power-system engineer. Nonetheless, the almost complete absence of currently sponsored research programs of interest to the power industry turns the young electrical engineer with an inquisitive mind, and, perhaps more importantly, his professors, to the more glamorous and immediate problems of other fields. The result is that the student whose turn of mind would inspire him to seek advanced training, in order that he might be prepared to solve research and development problems more adequately in his future career, turns away from power-systems engineering. Yet, in the long run, there are few in the power industry today who would admit that the industry does not require the services of the most competent engineers.

In other phases of the electric power field not discussed in detail the situation is similar. In nearly every phase, important technical developments have taken place with which the engineer should have a thorough knowledge, rather than a vocabulary acquaintance, when he enters upon his career. Yet the increasing diversification in education required by the development of the industry makes possible less penetration rather than more. Although improvement in methods of presentation and the elimination of less essential material have helped to keep pace, these factors alone are inadequate. For example, the development of automatic process controls and automatic devices in nearly all phases of industry requires that the competent industrial engineer be thoroughly familiar with transient phenomena, feedback control systems, servomechanisms, and magnetic amplifiers, as well as industrial electronics, all of which have important fundamental aspects that are best taught in organized classes and are not easily absorbed on the job. Yet none of these topics was included in the engineering curriculum of 25 years ago and there is little room for them in the 4-year curriculum of today. Similarly, a designer of large electric equipment in nearly every case requires a thorough training in the recent developments of heat transfer, and would profit greatly, for example, by further study of electric and magnetic fields and fundamental behavior of solid, liquid, and gaseous dielectrics. Yet any comprehensive treatment of these topics is beyond the range of the 4-year curriculum, and is not easily acquired.

There have been in the past, and will be in the future, many electrical engineering graduates employed in industry who do not require a high degree of specialized training. However, the day has arrived when the truly competent professional electrical power engineer has need for a group of fundamental subjects requiring more than the usual 4-year curriculum to provide them. Formal graduate training in adequately organized courses is essential to meet these needs. It is the task of the colleges and industry to work together in meeting them.

Mechanism for Hand Closing of Circuit Breakers

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IN THE ORDINARY application of power circuit breakers, the most desirable method of operation consists of d-c solenoid mechanisms for closing and tripping, supplied by a storage battery. When this is not suitable, the next choice is a dry metallic rectifier for closing from some a-c source and either current transformers or a capacitor device for a-c tripping. In some applications requiring only a single isolated circuit breaker, these methods of operation may not be desirable because of battery maintenance or because an auxiliary control transformer for a rectifier supply would have to be connected to the incoming line ahead of the circuit breaker.

On the other hand, direct manual closing of power circuit breakers is not desirable because of the relatively high force and speed required to make the operation safe in case the circuit breaker closes against a faulted circuit. This is particularly true of magnetic power air circuit breakers because the fault current may begin at a longer contact separation. Consequently, there is some need for a device to close magnetic power air circuit breakers without an external source of electric power.

A review of the possible means for doing this has led to a hand-charged spring device, which when released always closes the circuit breaker with proper speed and power. This method of storing energy in a spring gives reliable availability and may be arranged for simple operation.

The force required to close most circuit-breaker contacts rises very rapidly toward the end of the closing stroke as the contacts touch. If a circuit breaker happens to be closed on a faulted circuit, large blowout forces may be added near the end of the closing stroke. Hence, in the actual design of a spring closing mechanism, the linkage between the closing spring and the contact arm must be arranged so that a relatively low force is delivered to the contacts at the beginning of the motion and a relatively high force at the end of the closing motion.

Figure 1 shows a side view section of such a device developed especially for magnetic power air circuit breakers that are applied almost exclusively in metal-clad switching equipment of the horizontal drawout type. The closing spring pushes against the frame of the mechanism at the left and against the weight on the right. In normal duty, this closing device is operated entirely from the outside of the metal-clad switchboard cell with the door closed. An escutcheon, built as an integral part of the device, extends flush with the outside of the closed cell door, with facilities for spring loading, tripping, and for visual indication of spring loading, circuit-breaker contact position, and number of operations.

Mechanical features are included in the device that make its operation safe and simple so that a highly trained operator is not required. It has been designed so that it is possible to close the circuit breaker slowly for inspection and maintenance operations and to leave the circuit breaker in the drawn-out disconnected position with the cell door closed.

This device was designed for magnetic power air circuit breakers of 150 and 250 megavolt amperes at 4.16 kv and 150, 250, and 500 megavolt amperes at 13.8 kv. The maximum momentary rating among this class of circuit breakers is 60,000 amperes. Extensive tests in the East Pittsburgh high power laboratory were made in the development of this device. During the performance of these tests a current of 65,000 amperes at 4.2 kv was closed and latched successfully.

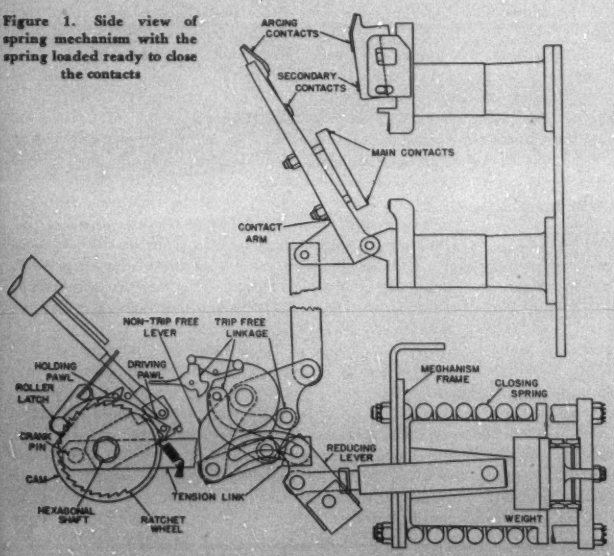

Figure 1. Side view of spring mechanism with the spring loaded ready to close the contacts

Digest of paper 51-25, "A Spring Mechanism for Hand Closing of Magnetic Power Air Circuit Breakers," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Some Design Criteria for Automatic Controls

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THE EARLIEST, and most direct, method of analyzing automatic control systems is based on the solution of the differential equations of the system for some initial disturbance. This transient analysis is general and, seemingly, may be applied to any problem which can be formulated in differential equations. However, even with the aid of the powerful methods of the Laplace transformation, synthesis of a complex control is largely a cut-and-try process.

In synthesizing a control, the problem, after stability is achieved, usually is to choose the sensitivity factors, time lags, and inertias which will give as rapid a response to disturbances as is consistent with reasonable deviations of the controlled variables.

For many kinds of single-loop control systems the method of frequency analysis has been developed into a useful tool. However, some kinds of aircraft engine controls have two controlled quantities (speed and torque) and two variables available for controlling (propeller pitch and fuel flow). These quantities are interrelated within the power plant in such a complex way that the transient analyses method seems to be the only way of dealing with the problem.

In the case of controls analyzed by the transient method, it has been proposed that the "control area" be used as a design criterion. If the response is known to be overdamped, it is proposed to compute the area included between the curve of a step function disturbance and the response curve and attempt to minimize this quantity. However, many controls require a faster response, that is, slightly oscillatory, and further, the degree of damping obtained in a control is one of the unknown quantities in the problem. In fact, the criterion of minimum control area applied blindly is likely to produce a response which becomes more violently oscillatory as the net area approaches zero.

Contemplation of the overshoot in such an error curve suggests a more useful criterion than the control area. It can be seen that the initial error will always be present in many physical control systems, but the magnitude of the error at later times may be minimized by suitable selection of control sensitivities. Hence, study of an error curve weighted in accordance with some function of time would lead to a more useful criterion. One such weighted error curve would be simply t times the error.

The control area and the weighted control area can be calculated from the Laplace transform expression for the response to a unit step function change in setting. If the transform of the response is

$$n(S)=\frac{1}{S}\,\frac{a_mS^m+\dots a_2S^2+a_1S+a_0}{b_rS^r+\dots b_2S^2+b_1S+b_0}$$

then the Theorem of Final Value can be applied

$$\operatorname*{Lim}_{t\to\infty} N(t)=\operatorname*{Lim}_{S\to 0} Sn(S)=a_0/b_0$$

provided that $b(s)$ is such that the system is stable, that is, has positive damping. This can be determined from the Routh-Hurwitz criterion without finding the roots of $b(S)=0$.

If it is desired that the control eventually reach the new setting, then $a_0=b_0$. With this proviso, the error is $N(t)-1$ and the "control area" is

$$A_{10}=\operatorname*{Lim}_{t\to\infty}\int_0^t [N(\tau)-1]\,d\tau=\operatorname*{Lim}_{S\to 0} S\left[\frac{n(S)-1/S}{S}\right]=\frac{a_1-b_1}{b_0}$$

provided the system has positive damping.

The weighted control area may be obtained by a similar method and is

$$A_{11}=\operatorname*{Lim}_{t\to\infty}\int_0^t \tau[N(\tau)-1]\,d\tau=\operatorname*{Lim}_{S\to 0} -S\left[\frac{1}{S}\,\frac{d}{dS}(n(S)-1/S)\right]$$

or

$$A_{11}=\frac{(a_1-b_1)b_1-(a_2-b_2)b_0}{b_0^2}$$

provided the system has positive damping, and that $a_0=b_0$.

These quantities are simple functions of the coefficients of the transform expression and depend only on the coefficients of the S^2, S, and constant terms. This is not surprising as these coefficients contain the products of all the roots of $b(S)=0$, taken in various groupings.

For design purposes $A_{11}=0$ is often used but leads to a somewhat underdamped response (in a second order system, the damping ratio would be 0.5). However, the ratio $R=A_{11}/(A_{10})^2$ has the property of being almost independent of b_0 and hence of the product of all the roots, and a value of R which gives a very satisfactory control is $R=-1/2$. This gives a damping ratio of 0.7 in a second order system.

Some classes of regulators are intended to reduce the system response to zero following a step disturbance.

In such a case we may have:

$$n(S)=\frac{1}{S}\,\frac{c_mS^m-\dots c_2S^2-c_1S-c_0}{b_rS^r-\dots b_2S^2-b_1S-b_0}$$

and $c_0=0$ to give the proper final value. The control area is then:

$$A_{00}=c_1/b_0$$

and the weighted control area is:

$$A_{01}=\frac{c_1b_1-c_2b_0}{b_0^2}$$

provided that $c_0=0$ and the system has positive damping.

Digest of paper 51-99, "Some Design Criteria for Automatic Controls," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Further Development of Fluid Mappers

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FLUID MAPPERS are fluid-flow devices for visually simulating electrostatic, electromagnetic, heat conduction, and other analogous situations. The writer has described fluid mappers in his first[1] paper on the subject, and it is called the "first paper" herein.

Before Hele-Shaw's work of half a century ago, it was known that an ideal (nonviscous) fluid flowing within suitable boundaries theoretically could simulate electrostatic and other fields. At any one location, the ideal fluid's velocity, taken across the flow space, would be constant, whereas, with a real (viscous) fluid in streamline flow, there would be a parabolic velocity distribution. Hele-Shaw was the remarkable pioneer who showed that, nevertheless, the real fluid also would give accurate simulations if the flow space were made thin enough. Hele-Shaw's methods were not carried on; though remarkably accurate, they were costly and inflexible.

In fluid mappers developed by the writer, the upper plate (of plate glass) is retained. But Hele-Shaw's lower plate is replaced by a slab of artificial stone (dental stone) cast on plate glass to make it flat. Also, the writer's invention of the sandbed as a distributed source carries the fluid mapper into the extremely complicated realm of distributed source phenomena.

Dental stone powder costs only 15 to 20 cents a pound. Thin slabs a few inches across may take only a pound; larger slabs, up to a foot square, may take four pounds. With some plate glass, a tray, two or three tanks, some rubber tubing, some brass pieces for molds and barriers, some potassium permanganate, some dental powder, and a few other knickknacks, anyone, for a few dollars, can set up a fluid mapper laboratory for demonstrating a great variety of cases. By adding some screen material and shotted metal, sandbed types of mappers become available.

Fluid mapper techniques are well enough developed so that many fields can now be simulated accurately by applying tested routines to building and operating the mappers. Like all other devices, they have their own special problems, troubles, and limitations. Further invention, research, and development of additional techniques are needed.

Fluid mappers as now developed fall into three main types, all represented in Figures 1 and 2.

At the right in both figures is a slab without a sandbed—the first type. The sources are simple wells of any shape or size. The bottom-up view, Figure 1, shows the plaster feet added to the plaster slab, the celluloid well bottom plastered on, and the connector tubes plastered into the well bottom. Anyone can soon learn to make such slabs.

The second type, at the left in Figures 1 and 2, is to operate as a slab with a sandbed. A screen is mounted horizontally across the well, to support the sandbed, with a plenum chamber below it.

The third type, at the top in both figures, is the isolated sandbed, or sandbed without a slab. Between the bottom and the screen is the plenum chamber, and the sandbed is built above the screen.

A complete fluid mapper of the first type is in operation in Figure 3. The two wells are acting as sinks, their tanks being nearly empty, with the right tank lower than the left. Figure 4 shows a flow pattern obtained with this setup, the tank levels being the same.

Figure 5 shows the pattern made with a mapper of the second type. The entire round sandbed area is acting as a uniformly distributed sink. The sandbed margin is not an isopressure line. This is very different from Figure 4, wherein the edge of a well acts as a boundary, or an isopressure line.

The third type, an isolated sandbed, is shown in Figure 6. Here, the boundary of the sandbed is an isopressure line as it is open to the tray water.

The foregoing serves to describe the general nature of fluid mappers. Space is not available here to describe numerous techniques for making and operating mappers in routine fashion. Many were covered in the first paper. Since then, the writer has continued the development work. Earlier techniques have been improved, some have been replaced, and new techniques have been perfected. These will be included in a manual or book on fluid mappers and field mapping, now in preparation. Very little can be said here about the various analogous field phenomena that fluid mappers can be made to simulate. For this, the first paper may be consulted; also the second,[2] on soap film and sandbed techniques; and the third,[3] in which fluid mappers serve to verify certain electromagnetic propositions.

PURPOSES OF THE ARTICLE

TECHNIQUES now well developed will serve for making and operating fluid mappers for portraying an immense variety of the more ordinary situations. In this paper and in every other way, the writer wishes to encourage all who want to get some experience with fluid mappers. Their potential value in solving field problems

Essential text of paper 50-267, "The Further Development of Fluid Mappers," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Published in AIEE *Transactions*, volume 69, part II, 1950, pages 1615–24.

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Figures 1 and 2. Bottom (left) and top (right) views of the lower members of the three types of fluid mappers. The upper member, the plate, is always plate glass

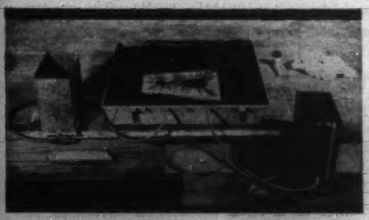

Figure 3 (left). A complete fluid mapper of the first type in operation

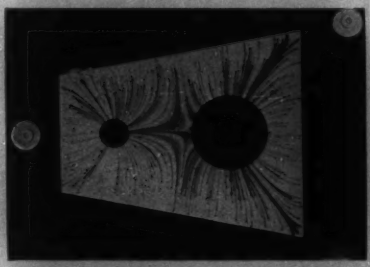

Figure 4 (right). Direct view of flow pattern. To produce this pattern, the tank levels were made equal

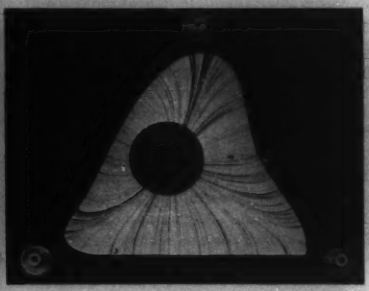

Figure 5 (left). A mapper of the second type, a sandbed within a slab. The sandbed here acts as a uniformly distributed sink. Note the kernel

Figure 6 (right). An isolated sandbed, a fluid mapper of the third type. Note the kernel and the ridge-line

and their great value as teaching tools warrant experimentation on a wide front.

At the same time, it must be recognized that fluid mappers, like all other devices, have their inherent errors, defects, and limitations. By describing some of these, two purposes are served. First, those who are making fluid mappers will learn something of how to avoid trouble, or to minimize its effects. Second, further invention, research, and development on fluid mappers are needed in order to remove the present handicaps. Graduate students and others will find a number of research problems herein.

PROBLEMS

Slab Permeability. Slabs made of dental stone are slightly permeable, and there is always a little fluid leakage through the slab. All experience strongly indicates that this effect is completely negligible; but nevertheless, it should be measured to make sure.

Slab Erosion. This is not mechanical erosion. It is disappearance of slab face material due to its going into solution. Calcium sulphate, the main ingredient, is slightly soluble. The rate of erosion has not been measured. It appears that greatest erosion occurs where flow space velocities are highest. Something should be known about erosion rates in order to know how long a slab may be used before being discarded or resurfaced. For accurate work, new uneroded slabs can be used.

Erosion might be stopped by saturating the water with calcium sulphate. This has not been tried. Treatment of the surface to form insoluble calcium stearate, and use of soft soap to form calcium oleate, have been suggested. The writer has used Spred Satin, a synthetic rubber emulsion paint, to stop erosion. However, with its use it was discovered that with permanganate used for dyelines, a permanent pattern record was formed. The erosion problem needs further attention.

Slab Resurfacing. Flat slabs can be resurfaced quite easily. A large sheet of waterproof silicon carbide cloth,

grit number 100 (Minnesota Mining and Manufacturing Company) is placed face up on plate glass. A little water is poured on it. The wet slab, face down, is skated around on the cloth with a random motion. After flushing off the ground plaster and wiping off the water, a piece of plate glass is pressed to the face. Where good contact occurs,

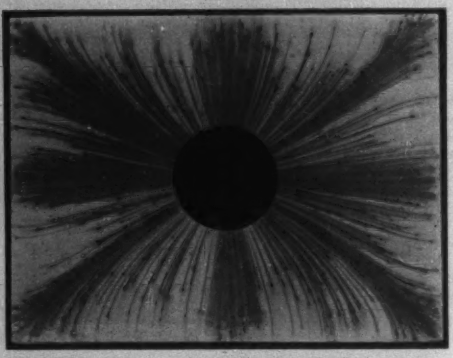

Figure 7. Permanent record slab made with potassium permanganate crystals on a slab covered with Spred Satin

a water film appears. A good distribution of such areas seems to indicate flatness. However, all this should be looked into further and checked.

Slab Materials. Plaster, so far, is the prime material for slab making. The writer's early slabs were made of patching plaster. Plaster of Paris would do. These, along with dental stone (artificial stone), are basically calcined gypsum. These are all plasters, even though the dental product is called stone in dental circles. Duroc, the newest dental stone, is the smoothest and hardest; its setting expansion is only 0.05 per cent. With all the numerous things that can be done cheaply and easily with plaster, this material is most attractive.

However, plaster erodes, and some attention should be given to developing plastic or metal slabs for permanent purposes.

Very Large Slabs. The writer's largest slabs are one foot square. The same routines would turn out slabs up to 18 inches square, and perhaps 7/8-inch thick. However, still larger slabs may be needed, and problems of distortion may be encountered. The plate glass on which the slab is cast may bend, unless adequately supported; the slab might need extra supports to maintain its own flatness in operation; and in operation extra spacers may be needed for the top plate. Techniques might be worked out for casting a large slab in sections and placing the sections edge-to-edge.

Record Slabs. Excellent permanent record slabs are easily made. Spred Satin, made by The Glidden Company, Cleveland, Ohio, is painted onto the wet slab face after excess water is mopped off. In a few minutes the paint is set well enough to permit operation. By sprinkling with the potassium permanganate crystals a "floor pattern" is formed; the dye lines are on or close to the floor of the flow. A chemical reaction quickly takes place. The record slab, Figure 7, was made on December 9, 1949. It is as clear and sharp today as when it was new.

The problem here is to change the painting job from an art to a science. Brush painting is somewhat tricky, and irregularity of thickness sometimes changes the flow space enough to cause error.

Record slabs are very beautiful. As to use, they make fine teaching aids, and they often eliminate photography. The slab can be traced directly as soon as the record is formed.

Fluids. The writer has used air as the fluid, but the smoke formed by reacting hydrochloric acid droplets on the plate with ammonia fumes diffuses too much to form a sharp pattern.

Tap water holds first place for demonstrations, and it serves for accurate work in many cases. However, inertia effects may enter in to spoil the desired streamline flow when pattern velocities are made high enough to make the pattern sharp. This is the case in Figure 8, where the break-away point is very close to the wing tip. In Figure 9, velocities have been reduced to where inertia effect is practically eliminated, and the break-away point has moved back to where it would be if a heat-flow field were being simulated. However, the pattern is somewhat vague; too much lateral diffusion of the dye occurs at the reduced velocities.

The way out of this dilemma is to go to a fluid of high viscosity. Hele-Shaw used glycerine, but that is costly. The fluid of choice today is water with Methocel, a Dow Chemical Company product. Methocel, a cellulose ether, is a nontoxic colloid. Two per cent by weight of the type known as "Methocel 1500 centipoises" in water gives a viscosity of around 1,500 times that of water. It then can be diluted.

Investigation with a variety of mappers should be carried out varying shapes, flow space thickness, and viscosity. It would be desirable to know in advance something about the viscosity needed to eliminate inertia effect.

Pattern Levels. Crystals resting on the slab form a floor pattern. It is a "slow" pattern, as velocities near the floor are low. Diffusion of the dye sometimes results in lack of sharpness of pattern.

The crystals can be stuck to the plate with Cutex to form the beginnings of a ceiling pattern. The dye lines then sink somewhat, thus getting into higher velocity levels; by moving faster, they diffuse less, and often are very sharp lines.

When methylene blue crystals and permanganate crystals are attached to the plate, side by side, it is found that the tendency to sink is very different for the two dyes. If the flow rate is lowered until the permanganate line drops to the floor in 1/4 inch of travel, the methylene blue line will carry along high and sharp for many inches.

Much work needs to be done on the dye-line problem,

and it may be that one or two other dye crystals suitable for mappers may be found.

Dyes and Dye Effects. Potassium permanganate is cheap and safe to work with; its stains are easily cleared up;[1] and it is the best dye for most fluid mapper purposes.

Methylene blue gives much sharper lines; it is safe to work with; but its stains are not removable. The hunt for methylene blue in crystal form must go on.

A dye undoubtedly affects viscosity, but there is no evidence that this is serious. Again, this effect should receive research attention.

Advancing Dye Front. If permanganate dust is stirred into a tank feeding a source, the precolored water entering the flow space demonstrates an advancing dye front. The effect is striking, and it may have a meaning which might be found useful. This effect should be investigated in further detail.

Flow and Potential Control. When the problem has such properties that definite rates of flow of sources and sinks must be set up, this can be done by using connector tubes of calibrated resistance and adjusting the heads accordingly. The design can be handled so that flow space resistance can be ignored, or nearly so.

In the other type of problem, given potentials at sources and sinks and boundaries must be simulated; this would call for setting up predetermined isopressure values at these places, which is not easy to do. The techniques have not been worked out, and the apparent difficulties involved in measuring pressures may not yield to effort along this line. Instead, a series of cases can be set up, a partial analysis of each pattern made, and data secured for a curve that will indicate the fluid mapper setup to use.

Edge Effects at Isopressure Boundaries. In much fluid mapper work it is safe to assume that an isopressure line is coincident with the edge of a well or with the open edge of a slab. However, this is not strictly so, and the departures should be investigated. Also, when a well is small in width compared with the flow space thickness, there can be a considerable departure from coincidence. Such problems ask for attention.

Edge Effect Along Barriers and Obstacles. Where flow in the flow space is bounded by an obstacle or barrier, another edge effect occurs because fluid velocity at the barrier is zero. In the first paper[1] it is suggested that when necessary, this be approximately compensated for by "cutback," that is, by cutting back the barrier (or obstacle) from where it otherwise should be by an amount equal to one-fourth of the flow space thickness. Even so, there are flow phenomena in this region needing consideration. For example, at which level should the pattern be set up to get the truest simulation?

Stability. The use of a thin flow space is required for two reasons. One is to minimize edge effects. The other is to secure stability. With too large a space the fluid wanders, and patterns at different levels will not coincide. No one as yet knows anything about the upper (stable) limit of flow spacing for a given case.

Swirl effect[1] occurs when fluid enters from a small source (or shoots into a well from the connector tube) rapidly enough to alter the pattern in the nearby flow space. Crowding gauze into the lower part of the well will cure the difficulty. Other means of control of this inertia effect would be welcome.

Disturbing Influences. Local disturbances are caused by

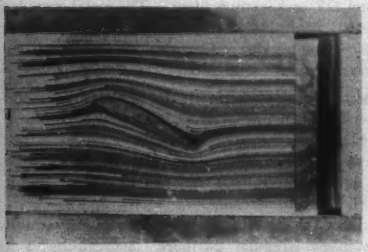

Figure 8 (left). With velocities high to get sharp pattern lines, inertia effects moved the break-away point nearly to the wing tip

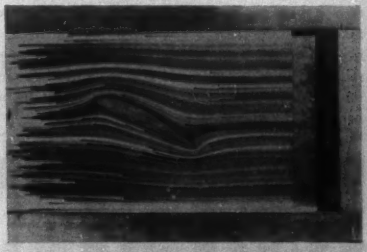

Figure 9 (right). With lowered velocities, the inertia effects drop out and laminar flow prevails. Lines are more diffuse

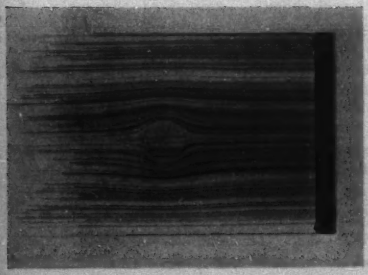

Figure 10 (left). A semiobstacle case with flow spacing two to one, representing permeability or conductivity ratio of eight to one

Figure 11 (right). A closer view of the semiobstacle pattern

placing crystals in the flow. If permanganate is used, it is doubted if sprinkling is ever heavy enough to disturb the general pattern seriously. Nevertheless, this definitely calls for research. Another kind of disturbance occurs when a slab of infinite size is needed, but one of finite size must be used. How near to the central phenomena can the edges be brought without seriously affecting the central pattern?

Barriers. Loose barriers (movable) are easily cut from rubber sheet. But such sheet varies in thickness. With a complete barrier leakage is almost certain to occur unless *DC4* silicone grease is used for sealing.

Loose barriers for many purposes are also made from brass strips made from 1/16-inch stock.

To insure accuracy and no leakage, the writer has developed the fixed barrier. The slab is cast flat, as usual; then a plaster barrier is added by appropriate techniques.[4]

Depressions. Two media having different constants may be simulated by making a depression in the slab. The depression can be milled in. Techniques for casting the depression should be worked out.

Semiobstacles. The airfoil section of Figure 8 is a complete obstacle; all flow goes around it. With a semiobstacle, Figure 10, flow partly goes around and partly goes over or under it, depending on whether the attached piece is placed on floor or ceiling. The effect is the inverse of that obtained by using a depression. Simple, reliable, and accurate techniques for making semiobstacles are needed very much. In Figure 10, a piece of celluloid was attached to the plate with acetone. This is an easy way to make a good demonstration, but accuracy cannot be achieved in this way.

Change of Flow Space More Generally Considered. When two or more media must be simulated, at least two of which take up more than a small part of the area, the modification of slab or plate to modify the flow space accordingly may be quite a task. Of course, a flat slab can always be milled down; but faster and simpler techniques are needed.

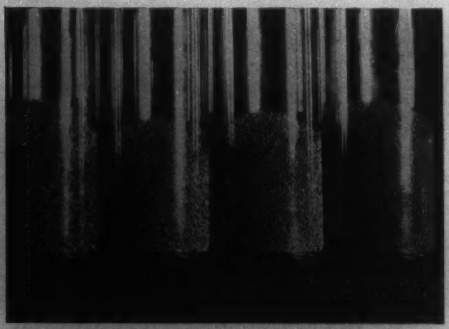

Figure 12. Shotted metal samples. Left to right: tin, bronze, copper, nickel. Tin and bronze are not suitable for sandbeds because of angularity

Figure 13. The point of inaction, shown in the bar of the dumbbell. Nickel shot used in the sandbed

Axial Symmetry Cases. There are two types of axially symmetric cases. For one, the flow space varies directly with the cube root of the radius; for the other, inversely with the cube root of the radius. So far, the writer has milled and scraped such slabs. If a terraced slab (milled, without scraping) would do, one operation would drop out. This should be tried.

Quasi-3-Dimensional Cases. If the flow space is kept thin enough to insure stability, but otherwise is varied at will; problems of this character could be solved: flow in a uniform sheet, having nonuniform resistivity; flow in a nonuniform sheet, having uniform resistivity; and the combination of these. Here again, the terraced slab is an inviting prospect.

Sandbed Materials. All of the writer's sandbeds (representing distributed sources) are now made of shotted metal, either nickel or copper. Floaters are avoided by using Aerosol *OT* as a wetting agent. The metal granules for a sandbed should be heavy, round, smooth, bright, stable, and of uniform size. The ideal shotted metal for sandbeds has not been found yet.

Shotted Metal Sandbed Problems. Four kinds of metal granules are identified in Figure 12. The tin and bronze are angular, and worthless for sandbeds as they will not pack uniformly. Nickel is best, even though darker than copper; it is smooth, round, and nearly uniform. But it is not available commercially.

Shotted copper is none too round; it lacks uniformity; and it has many irregular particles. Segregation is a threat. It can make fine sandbeds, but must be settled into place with care.

The sandbed presents several interesting packing problems, each of which would bear investigation.

Sandbed Flow Space Relationships. With existing techniques, reliable sandbeds can certainly be built and operated. However, there are several interesting relationships between grain size, sandbed depth, plenum chamber depth, sandbed area, flow spacing, and so on, that should be worked out so that safe limits could be established and applied to the design of sandbed types of fluid mappers.

Nonuniform Sandbeds. The nonuniform distributed source can be simulated by use of a nonuniform sandbed. There

are several obvious ways for modifying the sandbed, not any of which has as yet been tried out. All should be worked on, and techniques established.

Sandbed Plenum Chamber. The inclination is to make the plenum chamber below a sandbed much deeper than need be. A simple practical test is available for finding whether the chamber is deep enough. But here again, research is needed to guide design to the safe side.

The Kernel, and Lines of No Work. An apparent center within a distributed source or sink where the lines seem to converge is clearly seen in Figures 5 and 6. This point is called the kernel. Next, consider the flow lines in Figure 5 and interpret electromagnetically; the sandbed area represents a conductor section with uniform current density. Outside of the section the flow lines represent equipotential lines, but inside (over the sandbed) they represent "lines of no work." These phenomena, and their names, are well recognized. They are mentioned here in order to lead up to two other distributed source phenomena not so well known, the ridgeline phenomenon and the point-of-inaction phenomenon.

The Ridgeline Phenomenon. Distributed source fields are so very difficult that few solutions have ever been made, and very few good maps have been available. Until sandbed mappers became available, there was no simple way to set up a case so as to look directly at the complete field representation. Thus, such phenomena are quite unfamiliar to most. One phenomenon is very striking when it appears under certain conditions. It is a distinctive line, with the kernel located on this line. Such a line occurs in Figure 6, and it might be thought of as a "distributed kernel." The writer proposes to call it ridgeline.

The Point-of-Inaction Phenomenon. The writer has built sandbeds in which flow from one region tends to meet flow from another, with the meeting place over the sandbed itself. Such a meeting place, if happening outside of a source, results in what we call a singular point. There is then the temptation to call such a place, within a source, a "singular point within a source." Instead, it is here proposed to call it a "point of inaction." This phenomenon may not have been recognized. One case of it appears in Figure 13.

INVESTIGATIVE SANDBED WORK

THEORY ALONE can never yield much insight into phenomena within distributed sources except in the simplest cases. Since sandbed fluid mappers visually simulate these exceedingly complex situations, it may follow that fruitful experimental work might be done with sandbeds to gain insight and discover additional phenomena.

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A Study of Nuclear and Electronic Magnetic Resonance

K. K. DARROW

Since the discovery of magnetic resonance in solids, liquids, and gases in 1945, the phenomenon has been used in the determination of nuclear magnetic moments and magnetic field strengths, as well as in the study of crystal structure and relaxation times.

THE TITLE of this article might have been "Magnetic Resonance in Solids, Liquids, and Gases." The reader may think that the last five words of this alternative title are superfluous and that it would have been better to say "Magnetic Resonance, Period." If he thinks this he is overlooking what has been called "the fourth state of matter" but is more commonly called "the molecular beam." Molecular beams are streams of atoms or molecules crossing a vacuum all with about the same speed and in about the same direction. Their importance in this connection is that magnetic resonance was discovered in experiments on molecular beams. The discoverer was I. I. Rabi of Columbia University, and the date of the discovery was the winter of 1937–38. Now having done historical justice to Rabi, I confine the remainder of this brief account to molecular resonance in solids, liquids, and gases.

Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. First in a series of two papers on magnetic materials at high frequencies.

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In this limited sense, molecular resonance was discovered at the end of 1945. The discovery was made, simultaneously and independently, at both ends of the United States: by Felix Bloch and his group at Stanford University and by E. M. Purcell and his group at Harvard University.

It is not very often that any discovery in physics makes such a great and immediate sensation. In their impact on physicists, the initial papers rank with Bohr's first publication of his atom model, Schroedinger's first on his wave mechanics, the discovery of fission, the discovery of the positive electron, and a very few more. This was because the theory is basic and very simple, and the phenomenon clean-cut and very striking. Before displaying the phenomenon I will give a brief description of the apparatus as it was set up in some of the experiments of Purcell.

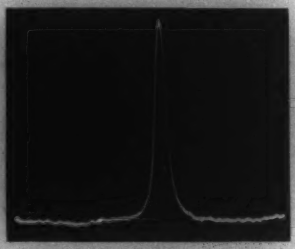

Figure 1. Proton resonance peak obtained with water containing ferric nitrate

Illustrations courtesy *Physical Review*

The sample—let us here think of a tube of water for definiteness—is immersed in a strong and constant magnetic field between the pole pieces of a powerful magnet. The field strength will be denoted in what follows by H; for definiteness the reader may hold in his mind a value of 10,000 gausses. Around the sample is wound a coil upon which is impressed an alternating voltage of radio frequency. The symbol for the frequency shall be ν, and its order of magnitude tens of megacycles for nuclear resonance and thousands of megacycles for electronic resonance. Measurements of the impedance of the coil show that absorption of radio-frequency energy is taking place in the sample; it is possible to calculate the absorption, and to plot it as a function of ν when H is held constant (or the other way about).

When absorption is thus plotted against frequency for constant H, one finds a smooth curve. This is of no importance in the present connection. What is of importance is that under the right conditions the smooth curve is interrupted by a magnificent peak, high and sharp enough to be called justly a needle. This is the phenomenon of magnetic resonance. There is probably nothing else that appeals to an experimenter or, for that matter, to a theorist as much as does a curve presenting a high sharp peak. Here they find it, as Figure 1 (for nuclear resonance) and Figure 2 (for electronic resonance) portray. Indeed, the peak of Figure 1 is narrower by far than the reader probably suspects. This is because he naturally assumes that the origin of co-ordinates and the axis of ordinates are somewhere near the left-hand side of the figure. Actually they are 15,000 times as far away toward the left as the peak is wide—and this is not even the narrowest peak which has been observed; it is one of Purcell's earliest, and it is shown here for its historical interest. Some of Purcell's peaks had a breadth less than 0.15 gauss, with the field strength of 7,000 gausses; even this minimal breadth was ascribed in part to inhomogeneities which were present in the field.

Turning to the theory, water consists almost altogether of three kinds of particles: nuclei of ordinary hydrogen atoms, which are called protons; nuclei of ordinary oxygen atoms; and electrons. The oxygen nuclei are nonmagnetic and produce no resonance. The electrons are very magnetic and yet produce no resonance, for a reason which will be mentioned later.

Beginning with the protons, each proton is to be visualized as a tiny bar magnet, of fixed and permanent magnetic moment, hereinafter to be denoted by μ_p. The value of μ_p is known from experiments of other kinds, and therefore may be taken as a quantity established in advance of the experiments. This magnetic moment may be oriented in various directions, and of these we will take two. One is the direction into which the magnetic field H would like to turn the tiny magnet, and, in fact, would turn it if the proton were a compass needle. Suppose that the south pole piece of the magnet is above the north pole piece; then this particular orientation is the one in which the north pole of the proton is turned up and the south pole down. It is called the "parallel" orientation. The other is the orientation in which the north pole of the proton is turned down and the south pole up, and it is called the "antiparallel" orientation.

Now the amount of work which must be done upon a proton to turn it from its parallel to its antiparallel orientation must be calculated. This is easy to do by classical methods. Let θ stand for the angle between the direction of the proton and the direction of the field; θ is zero for the parallel orientation and 180 degrees for the antiparallel. The torque on the proton is $-\mu_p H \sin\theta$. The work which it is desired to compute is the integral of the torque from θ equals 0 degrees to θ equals 180 degrees. The integration is simple, and the result is:

$$\text{Work} = 2\mu_p H \qquad (1)$$

Now one of the basic doctrines of quantum theory must be invoked. This is the doctrine that when energy is absorbed from electromagnetic waves of frequency ν, it is absorbed in units or parcels or quanta equal to $h\nu$. Here h stands for Planck's Constant, of which the value is very well known from experiment. It is unfortunate that in the theory of magnetic resonance both capital H and lower case h must be used, but it would be worse if one were to change either symbol. Thus we convert equation 1 into the following:

$$\nu = 2\mu_p H/h \quad \text{(proton)} \qquad (2)$$

and this equation embodies the theory of magnetic resonance for the proton. The frequency of magnetic

resonance, for proton-containing substances, is given by equation 2; if it were otherwise this article would not have been presented. For a field strength of 10,000 gausses it is located at 42.6 megacycles per second.

Turning from the proton to the electron, the equation for magnetic resonance of the electron is equation 2 with the substitution for μ_p of μ_e, the magnetic moment of the electron:

$$\nu = 2\mu_e H/h \quad \text{(electron)} \tag{3}$$

The magnetic moment of the electron is about 700 times that of the proton, so the resonance must be sought at a correspondingly higher frequency; or if one wants to locate it at the same frequency, the magnetic field H must be reduced correspondingly.

However, magnetic resonance of the electron cannot be found in water, nor indeed in most substances. This is because of a quantum-theory law which may be paraphrased roughly by saying that in most substances the electrons behave as though they were rigidly coupled together in pairs and the members of each pair were pointed in opposite directions. Thus, each pair of electrons forms a nonmagnetic whole on which both constant and alternating fields have no effect. To find the electron resonance substances belonging to either of two classes in which this coupling does not occur must be used, or to express it better, substances in which some of the electrons are uncoupled.

One of these classes is that of the strongly paramagnetic salts. For these the electron resonance is located at the frequency given by equation 3; it must be mentioned, however, that often there are several peaks instead of one, for reasons too deep to expound here.

The other class is that of the ferromagnetic metals and alloys. For these, equation 3 is incorrect because the field inside a strongly magnetized substance is not identical with the applied field H. There is, in fact, a quantity called "induction" and denoted by B, the exact interpretation of which is rather baffling, but at least it is measurable. It is not intuitively obvious whether in equation 3 H should be replaced by B or by some combination of B and H. Kittel, however, developed the theory, and showed that equation 3 must be replaced by the following equation:

$$\nu = 2\mu_e \sqrt{BH}/h \tag{4}$$

In ferromagnetic substances the electron resonance is actually found very nearly at the frequency given by equation 4; the small discrepancy can be explained by more profound theory.

The applications of nuclear magnetic resonance are already numerous, and brief mention will be given to only a few.

To a nuclear physicist, one of the most interesting uses of magnetic resonance is the determination of nuclear magnetic moments. In this application μ is the unknown in equation 2. Some 40 nuclear moments have already been measured in this way. Among them may be listed the moment of the proton itself, for although μ_p had previously been measured by other methods, this one is the most accurate by far.

To an experimental physicist in or out of the field of nuclear physics, magnetic resonance of a nucleus of known moment—preferably the proton—affords an excellent way of measuring magnetic field strengths. In this application H is the unknown in equation 2. This method, already much in use, compares well with the older methods and in many cases is superior.

Magnetic resonance may also be applied to the study of crystal structure. Considering a substance containing protons, each proton is subjected not only to the applied magnetic field H but to the magnetic fields of its neighboring protons as well. These are much weaker than H, but they are not quite inappreciable, and they bring about a broadening or a shifting of the resonance peak from which the distance from any proton to its nearest neighbors may be calculated. Remember that protons cannot be located by diffraction of X rays, since they do not scatter X rays sufficiently. Magnetic resonance and the diffraction of neutrons furnish the only methods by which the locations of the protons in a crystal lattice can be determined. In liquids the resonance peak is likely to be narrower than in solids; this is true because the rapid motions of the nuclei—protons in water, for instance—blot out the effect just described.

Measured by volume of literature, though not necessarily when measured by other criteria, the study of relaxation times is the major application of magnetic resonance. This affords a pretext for delving deeper into the theory.

Returning to the case of protons in water, it may have been surprising that allusions have been made only to the parallel and the antiparallel orientations. It was permissible to ignore the others because the others do not exist. This is an illustration of perhaps the strangest of all the laws of quantum theory; it is, however, not only strange but also well attested, and one of the proofs is precisely the fact that magnetic resonance peaks are so

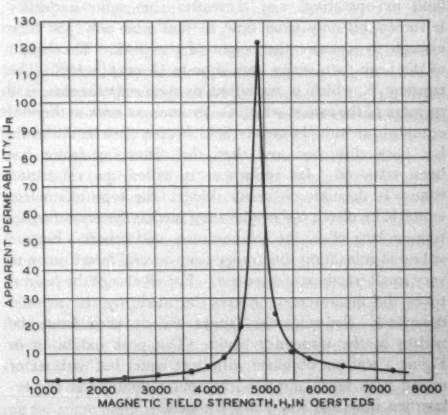

Figure 2. Electron resonance peak in annealed Supermalloy

extremely narrow and are located just where equation 2 says that they should be. In a sample of water in a magnetic field, all of the protons are either in the parallel orientation or in the antiparallel. Boltzmann's Law tells us how they are distributed between the two when thermal equilibrium prevails. It turns out that in thermal equilibrium at room temperature, out of 2,000,000 protons seven over 1,000,000 are in the parallel orientation and seven under 1,000,000 are in the antiparallel state. Not very much of a margin, and yet it is responsible for the whole effect, and (according to the theory) if this margin were to vanish the resonance peak would vanish along with it. Is there any experiment by which we can make the margin vanish or at least diminish, and in such a manner test the theory?

On examining this question we readily see that not only is there such an experiment but it is an experiment which is performed automatically whenever a resonance peak is measured. Consider the sample of water continually exposed to both the steady field H and the radio frequency. Every time a radio-frequency quantum is absorbed, a proton is turned from the parallel orientation into the antiparallel. It comes back eventually, but it does not come back right away, and until it comes back the margin is reduced correspondingly. Thus the height of the peak diminishes as the experiment goes on; this has been verified.

The height of the peak varies with time as $\exp(-bt)$. If it is wished to restore the peak to its original height, the radio frequency is turned off while leaving the steady field in operation, and thereafter the radio frequency is turned off only from time to time and only just long enough to measure the height of the peak. The height of the peak then varies with time as $(1-\exp[-bt])$. The constant b, which is measured in such experiments, is a measure of the rate at which the protons get back to thermal equilibrium with the steady field H after their equilibrium has been disturbed and then the disturbing factor has been removed. Its reciprocal is called the relaxation time. It depends on many things: the type of nucleus which is involved, the neighboring nuclei, the crystal structure or lack of it, the temperature, and others. Known values of relaxation time range from several hours down to very small fractions of a second. For all except the longest times the measurement cannot be made by the method described; the relaxation times are deduced from the widths of the resonance peaks. The peak exhibited in Figure 1 was not obtained with pure water but with water mixed with ferric nitrate; the solute diminished the relaxation time and sharpened the peak.

The closing paragraphs of this article have been reserved for what may well be deemed the most important quality—most important in this connection—of nuclei and of electrons. This is the angular momentum, otherwise known as "spin." It is important because it is responsible for the singular law of orientation which, in turn, is responsible for the sharpness and indeed for the existence of magnetic resonance. The law of quantum theory operates on the spin, and in the cases of the proton and the electron constrains it to point either in the parallel or in the antiparallel orientation. The magnetic moment is just dragged along to follow the spin.

Since the spin has been designated as the most important quality of proton and electron, the reader may well wonder why it did not figure in equation 2 or equation 3. It does figure in both, but it is concealed in the factor 2. The proton and the electron both have the same value of spin (and this, incidentally, is the only feature that they have in common). This is the smallest nonzero value of spin that any particle may possess. Its numerical value depends on the unit of spin chosen, and if $h/2\pi$ is chosen as the unit, then the value common to both proton and electron is 1/2. This is the reciprocal of 2. The factor by which $\mu H/h$ is multiplied in equations 2 and 3 is the reciprocal of the spin value of proton and electron, when $h/2\pi$ is chosen as unit of angular momentum.

There are many nuclei having other values of spin, all of which are integer or half-integer values of 1/2; they range as high as 9/2. For any of these, equation 2 is to be rewritten, with the reciprocal of the appropriate value of spin put in place of the factor 2.

The symbol p is introduced to stand for the spin of any nucleus, expressed in terms of $h/2\pi$ as unit. The general equation then is

$$\nu=(\mu/p)H/h \qquad (5)$$

and this shows that what is really measured, when a magnetic-resonance peak is located, is the ratio of μ to p. This is called the "gyromagnetic ratio." Thus, what magnetic resonance strictly gives us is a way of measuring, not the magnetic moment of the resonating particle by itself, but the gyromagnetic ratio of the particle; and this is how the reader will find the method described, normally and correctly, in the literature. However, the practical difference is slight, since usually the value of p is known from experiments of other types.

I add two more statements for the benefit of those who wish to pry further into the theory; others may ignore them. First, when the particle has a spin greater than 1/2, the number N of permitted orientations is greater than 2; the equation is $N=(2p+1)$. This does not result in the appearance of more than one peak; absorption always involves the passage of a particle from one orientation to an adjacent orientation, and equation 5 remains correct. The second statement I will illustrate from the cases of proton and electron ($p=1/2$, $N=2$). According to the newest form of quantum theory the spin is not 1/2, but $\sqrt{(1/2)(3/2)}$. The "parallel" orientation is not strictly parallel, but slanted to the field direction at such an angle that the projection of the spin on the field direction is 1/2; the corresponding assertion is made about the "antiparallel" orientation. Equation 5 retains its validity. Those who wish to pursue the topic furthur may study the articles by G. E. Pake in the *American Journal of Physics*.[1,2]

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A New Lightweight Rapid Transit Motor

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A BROADENING application field for the President's Conference Car (PCC)-type electric car has introduced new and more severe requirements in the design of its propulsion equipment. This has resulted in a new traction motor embodying the latest progress in design and manufacture, and particularly suited to dynamic braking at the high operating speeds currently coming into vogue. The application of the PCC car to high-speed suburban service, and the utilization of the same propulsion equipment for lightweight rapid transit service, have set the stage for a redesign of this equipment to meet the new performance demands. Whereas a speed of 35 miles per hour was rarely exceeded in city service, speeds of 50 miles per hour and above may be expected in rapid transit and suburban operation. Coincident with the increase in top speed is the requirement that dynamic braking be made available from these speeds without injury to the motor from overvoltage.

The new motor is designed to meet the above conditions and to incorporate other improvements resulting in more performance per pound of weight. An increase in the number of commutator segments and a shortening of the core allow an increase in the dynamic braking voltage. Refinements in the mechanical construction render the new motor better able to withstand the centrifugal forces experienced in high-speed operation.

The new motor shown in Figure 1 is rated 55 horsepower at 300 volts. The frame is suitable for the same truck mounting as the earlier motors. The characteristics are such that cars equipped with these motors will have the same operating characteristics as present cars equipped with the earlier motors.

The commutator is of the archbound design instead of the Veebound previously employed. This change is in accord with the modern trend in motor design, and is a highly desirable improvement. In addition, the segments and steel parts have been strengthened to better withstand high-speed operation. The commutators are seasoned by repeated cycles of heating and cooling while revolving at high speeds, followed by tightening.

The use of wedges has replaced the core binding wire for holding the windings in the slot. This eliminates the banding losses and also provides greater mechanical strength. Skewed slots are employed to minimize magnetic noise. The armature shaft, which can be replaced without disturbing the windings or commutator, has been increased in diameter to add stiffness for high-speed service. Hot-stacking of the core on the shaft has dispensed with the shaft keys. The omission of the commutator key permits a more accurate line-up of commutator segments with the core slots.

Bearing assemblies have been simplified to facilitate maintenance without sacrificing performance. The commutator end ball bearing, which locates the armature longitudinally, is carried in a cartridge-type assembly that fits into the bore of the framehead. The pinion end is fitted with a roller bearing to take up longitudinal movement of the armature. When the armature is removed, the complete bearing assemblies are removed with it, a feature that prevents the bearings themselves from being exposed to dirt. The armature conductors themselves are insulated with Permafil-treated glass, and the ground insulation is mica and glass.

Figure 1. New 55-horsepower 300-volt d-c lightweight rapid transit motor

The most significant contribution offered by the new motor is in the extended range of dynamic braking.

Below 40 miles per hour and down to approximately $1^1/_2$ miles per hour where dynamic braking begins to fade, the maximum braking effort is obtained with full field strength on the motor. Since the generated voltage on full field is directly proportional to speed, some means must be employed to hold the value within practical limits as speed is increased. The determining factor in arriving at the maximum desirable braking voltage is the volts developed between commutator bars. Experience has shown a value of 40 peak volts per bar to be the practical operating limit for 0.045-inch commutator side mica. In order not to exceed these limits when operating at speeds from 40 miles per hour up to the maximum of 58 miles per hour, field shunting is employed to reduce the generated voltage while holding a constant value of load resistance across the motors.

A test car equipped with the new motors has been operating for some months in high-speed suburban service in the city of Shaker Heights, Ohio, transit system. The performance of this equipment over the maximum speed range in both motoring and dynamic braking has given conclusive proof of the success of the design, and established the significant contribution which the new motor will make towards the development of modern transit systems.

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D-C Power Supplies

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THE PROBLEM of obtaining selective tripping of feeder circuit interrupters on d-c traction systems is an old one which has challenged the ingenuity of design engineers for many years. The ideal operating condition is one that keeps the feeder circuit breaker closed under all conditions of normal loads and quickly opens the interrupter when a short circuit occurs on its circuit, all other interrupters remaining closed.

Overcurrent tripping, because of its simplicity and speed, is an ideal method for clearing faults so near to the substation bus that the ratio of fault current to maximum load current is large. Overcurrent devices alone are inadequate for discriminating between normal loads and short circuits which are far enough from the substation bus to have current magnitude less than that of normal loads. For protection against the large proportion of faults that are of this latter class, tripping devices based on current rate-of-rise were developed and have been used successfully for many years. However, the application of such devices has relied largely on staged short-circuit tests and operating experience. Recently such a device, consisting of an impulse coil and d-c relays, has undergone extensive laboratory tests. Performance data have been developed to put the application and setting of the device on a definite basis comparable to a-c relay practices.

The impulse coil design is similar to that of a current transformer. The chief difference is that the iron core is broken up by a series of air gaps to prevent saturation by load currents. The relays associated with the secondary circuit should respond equally well on short circuits whether the fault occurs under no-load or full-load operation.

Two types of relays are used with the impulse coils. The *S* relay is a fast operating solenoid type with a biased winding to prevent tripping in case of a sudden drop in load current. It is used to quickly trip the feeder interrupter for nearby faults when the rate-of-rise is faster than that caused by normal car or train acceleration. The second relay, type *D*, is of the moving coil type with an electromagnet energized from the station control battery. The moving coil, with a fixed calibrating resistor connected in parallel, is in series with the *S* relay coil in the impulse transformer secondary circuit. For remote short circuits where the fault current takes a longer time to reach its maximum value, the secondary current causes the relay to close its contacts and trip the interrupter. On car or train accelerations, the relay may start to operate but will not travel far enough to cause tripping. Thus, it is possible to segregate heavy loads from short circuits and only trip the feeder interrupter under the latter condition.

Theoretical calculations of any traction system may be readily made from data now available. Relay settings may be made initially from these calculations as the feeders are put in service. Final adjustments then are made from the operating log record. The initial relay settings are made on the low or tripping side so that the adjustments, if necessary, are made in the direction of nontripping.

Most traction systems have considerable inductance in the d-c feeder circuits. The circuit interrupters produce large volumes of ionized gases which are readily directed to harmless areas. If they are not, they can cause short circuits with damaging effects. Much improvement in the technique of gas handling has been made in recent years.

Since the negative side of the d-c circuit is grounded on most traction systems, the structures surrounding the positive circuit interrupter should either be left isolated from ground or grounded through a ground protective relay with an operating coil of high resistivity. This precaution is safer to both personnel and equipment.

In unattended substations, service continuity demands the use of automatic reclosing apparatus so that the feeder interrupter may be safely reclosed as soon as the short circuit is cleared.

Figure 1. An uncontrolled 20,000-ampere 750-volt 12.5-millihenry arc

Figure 2. A controlled 20,000-ampere 750-volt 12.5-millihenry arc

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Engineering Must Have Prestige

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EVERY ENGINEER has a job to do that is not directly related to the project that he is working on, but which is important to the prestige of the engineering profession. That job is to let the layman know what he is doing, why he is doing it, and what the results would be if he failed to do it. In other words, publicity is an extra-curricular part of an engineer's responsibility.

A popular topic of conversation among engineers is the relatively low professional status of engineering. Almost always they will agree that the engineering profession is not accepted by the public as a profession in quite the same way as are the professions of medicine and law, and as soon as this conclusion is reached they feel a little sorry for themselves and cast about for reasons why the profession is not so well esteemed.

If the engineers can succeed in being objective about their profession and if they can look at the problem from a nontechnical point of view, they can usually think of a number of reasons why the public is not placing them quite on a par with the other professions. They usually say that the term "engineer" is misapplied; that engineering training is not right because it is too specialized or there is not enough time spent on cultural subjects and the humanities; that most doctors and lawyers work directly for themselves while most engineers are employees. If the discussion is carried on to its conclusion, it usually ends with a decision that there are several things that "they" (meaning the profession at large) ought to do.

While I do not agree that the state of affairs is quite as bad as many engineers seem to think, I do believe that the real reason for what lack of appreciation there is lies not so much in failures of the societies as in the failures of ourselves to publicize ourselves and our work. I believe it is an important part of our business to let people know what we stand for and what we are doing. I believe we can do this by being better mixers.

Engineers are not accepted as they should be because the public does not know about them, and the reason for this is that the engineers have not bothered to tell them. Engineers usually pay little attention to publicity because they are absorbed in their work. Because they know how important their work is, they take it for granted that the public knows it also.

Engineers depend too much on the societies to do the publicity work for them, and when they find that publicity has not taken root they are inclined to blame the societies. In this they are mistaken. The societies cannot do much of the needed publicity work; it can only be done individually by the engineers themselves. The doctors and the lawyers automatically get this job done because they work directly for the public and in the public interest. The engineer works just as much for the public interest, but more indirectly. Instead of working on his client's health or prestige, the engineer works on machines or devices or constructions that will themselves affect the public health or prestige. His work stands between him and his client. As a result, the public is apt to forget the personality behind the work, particularly if that personality remains hidden under a table of 7-place logarithms.

An important thing to remember is that it is not just for personal prestige or gain that engineers have a responsibility to keep their profession before the public. There is another reason far more important than that.

This is an age of engineering. Engineering has brought our civilization into existence and directed our way of life, and our civilization is sustained by engineering. It will take more engineering, perhaps much more than we think, to keep our civilization going in the future. Engineering must be able to attract our best men, our most public-spirited men. *The engineering profession must have prestige.*

Because our civilization and our way of life are so dependant upon engineering, it is essential that engineering be well represented in shaping public policies and in planning for the future. More public leaders must arise from the ranks of engineers. When engineering does get the prestige that it must have, the public will begin to look to the engineer for leadership.

The following comment recently appeared in a New York paper: "In a predominantly engineering civilization, a civilization surrounded and sustained by the work of the engineer and incapable of living an hour except for his efforts, it is remarkable how few engineers ever reach public prominence. We duly honor our poets and statesmen, our philosophers and soldiers and scientists, but we seldom know who our engineers are."

I am firmly convinced that the only reason why the public does not know who its engineers are is that the engineers have not bothered to tell them. It is not because the people are not interested. It is not at all because the work of the engineer is too technical. It is not because many of us work for an intermediary between us and our clients. It is mainly because we are content to remain out of the public view, because we would rather associate with our technical societies and our long equations. It is because we have too much of a tendency to feel that our accomplishments will do our publicity work. I believe the time is ripe for the engineer to step forward and to take the place of leadership in a technical world that is rightfully his, a place that only the engineer can fill as it should be filled.

Essential text of an article which originally appeared in *DODS*, newsletter of the Doings of the Denver Section of the AIEE.

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A Full Automatic Private Line Teletypewriter Switching System

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A full automatic teletypewriter message switching system has been developed for use in private line networks involving one or more switching centers and a multiplicity of local or long distance lines, each of which may have one or more stations. This system provides fast teletypewriter communication from any station to any other station or group of stations in the network.

IN THE YEARS before World War II a number of private wire teletypewriter systems had grown to considerable size—some of them spanning many states or even the entire country. About 1940 it was felt that a faster, more economical service could be secured by the use of automatic switching of teletypewriter messages, and the Bell Telephone system undertook the development of fully automatic arrangements. In October 1941 a full automatic teletypewriter switching system was placed in service for the Republic Steel Corporation, just in time to handle the rush of war business.

World War II prevented the installation of additional systems of this type and interrupted the development program. Experience with the Republic Steel system during the war proved not only its many advantages but the soundness of its basic features. Following the war, a wide interest in teletypewriter switching systems of this general type resulted in further studies and the renewal of the development program.

The studies indicated the need for even greater scope and versatility with such new features as the use of more than one switching office in a system and the full automatic handling of multiple address messages which are messages originating as a single transmission to be delivered to more than one receiving station. As a result of the development program the present system known as the *81C1* teletypewriter system was produced and placed in service for five large customers with nation-wide networks.

The *81C1* system provides efficient, accurate, and rapid handling of a continuous flow of messages between the various stations on extensive private line teletypewriter networks involving a multiplicity of lines and stations. It functions in such a manner that a message may be sent from any sending teletypewriter and recorded on any desired receiving teletypewriter or group of teletypewriters in a network without requiring manual handling or operating attention other than the original perforation of tape at the sending station and the removal of the typed message from the receiving machine or machines to which it was directed. The switching operations are entirely automatic and are under the control of directing characters punched at the head of each message in the original transmitting tape and end-of-message characters punched at the end of each message.

Individual line circuits are full duplex and may be operated at either 60 or 75 words per minute, thus permitting maximum economies for any line loading.

The general objectives considered and met by the design include efficient usage of line circuits, rapid delivery of messages, and accurate handling of traffic, as well as many other customer requirements dictated by their individual traffic patterns and problems. Different sizes of switching offices, the number of switching offices in a system, the number of trunks between switching offices, the number of stations in a system, the amount of traffic for local delivery in the vicinity of a switching office, the quantity of multiple address traffic, and a number of other variations must all be considered when a system is engineered. The traffic which industrial systems must handle consists, in general, of relatively long messages which must be transmitted over the systems with speed and accuracy. On the other hand, traffic for transportation companies, particularly airlines, consists, in general, of much shorter messages, a high percentage of which must be transmitted over the systems within very short intervals. The design of the *81C1* system anticipated these variable factors and permits the installation of systems which provide for them without special engineering for each case. Figure 1 shows an example of an *81C1* network now in service.

The Ford Motor layout is an example of a system where one very large switching office at Dearborn handles the traffic. In this case (see inset) there is a large volume of local traffic to be distributed to stations within a short distance of the switching center. Other large layouts in operation today show the versatility of the system.

Pan American Airways has a system in which there are three widely separated areas, each with its own community of interest. Each area is served by a switching office with lines radiating to stations in the area. Single trunks between switching offices at San Francisco and New York and between New York and Miami are sufficient to carry the traffic between the areas.

Eastern Airlines has a system in which there are two centers with a community of interest, each served by a

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switching office. In this case there is sufficient traffic between the switching offices at Atlanta and New York to warrant two trunks between them.

General Motors has a system where one large switching office located at Detroit is best adapted to handle the traffic. In this case, the heavy volume of business for the headquarters office is delivered at the switching center and distributed principally by telephone, messenger, and pony wire.

The Western Electric Company uses a large industrial system in which there are two major centers of traffic in New York and Chicago served by two switching offices. The large amount of traffic between these offices necessitates a group of interoffice trunks.

GENERAL METHOD OF OPERATION

EACH STATION in the system is assigned a 2-letter code, and in order to direct a message from any sending station in the system to any receiving station, the operator perforates in the sending tape the 2-character code of the desired station followed by a "Letters" signal. Of the 26 letters of the alphabet 20 are used for station code purposes, thus permitting up to 400 station codes. The letters *T*, *O*, *M*, *V*, *H*, and *Z* are not used for various reasons. The first four are apt to be produced in case of an accidental interruption or hit on an idle line, while *H* and *Z* are used for other switching functions which will be explained.

Referring to the block diagram, Figure 2, the path of a message first will be traced from a sending station which has exclusive use of a line (1) (numbers in parentheses indicate locations on block diagram of Figure 2). The message is perforated in a tape at the station, the text of the message being preceded by the 2-character code of the station of destination and followed by the characters, "Figures," *H*, "Letters," which indicate the end of a message. This tape is sent from the transmitter distributor which may be seen in Figure 3. No further action on this message is required on the part of the station operator.

The incoming line circuit (2) at the switching point associated with the line serving this station perforates the message in a tape on the receiving side of a reperforator-transmitter (3).

The reperforator-transmitter shown in Figure 4 is a machine which forms the heart of the switching system. This machine consists essentially of two parts, a receiver which perforates and prints tape identical with the tape made at the station, and a transmitter which transmits the signals represented by the perforations in the tape and which is so arranged as to transmit the last character perforated, thus eliminating the need for special tape feed-out arrangements to clear messages from the transmitter. The transmitting portion of the machine is so arranged that reading of perforated holes and the actual transmission can be controlled independently from external circuits when desired.

The presence of tape perforated with char-

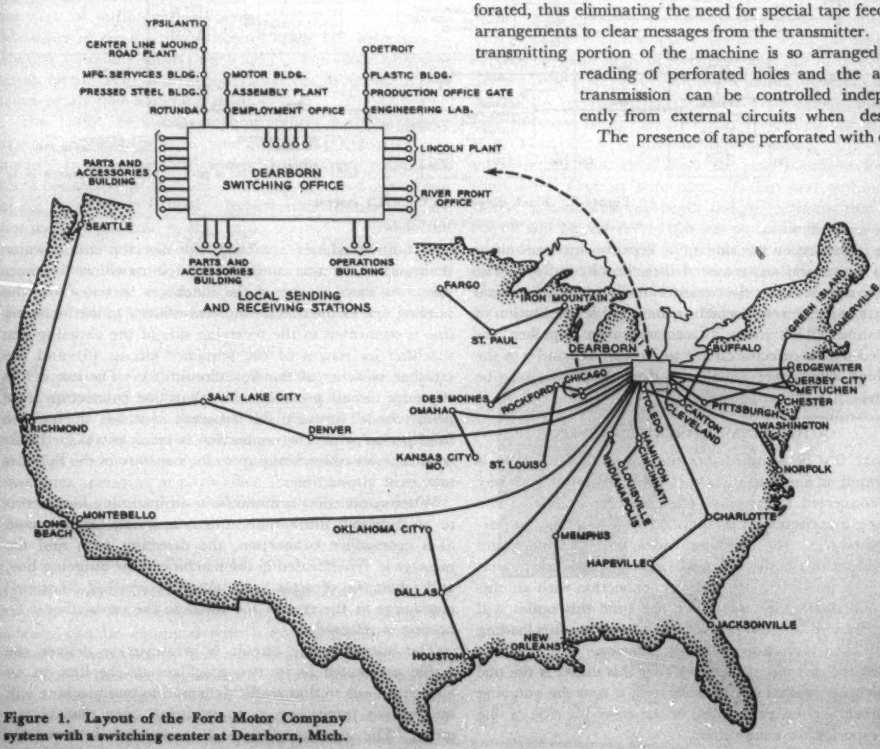

Figure 1. Layout of the Ford Motor Company system with a switching center at Dearborn, Mich.

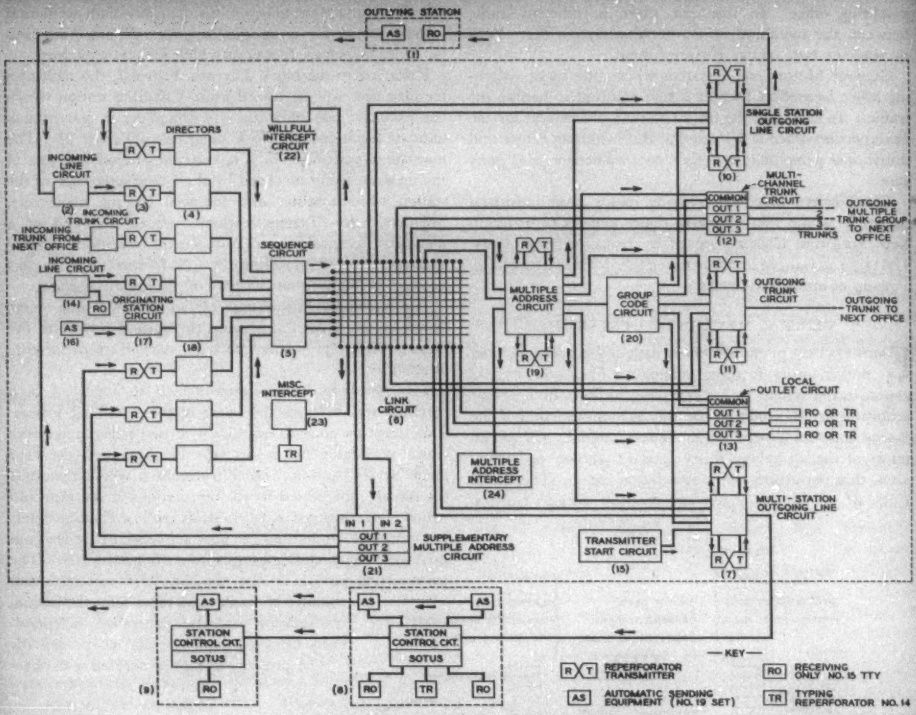

Figure 2. Block diagram of the 81C1 system

acters in the receiving side of a reperforator-transmitter brings into action an associated director circuit (4). The director circuit causes the reperforator-transmitter to read the first two characters which is the code of the station of destination. These two characters taken together are decoded by the director circuit to indicate the outlet of the switching office over which the desired station may be reached.

OUTGOING MULTISTATION LINES

It will first be assumed that the station of destination is located on a multistation line. A multistation line may have connected to it up to ten receiving stations. The outgoing line circuit (7) is equipped with two reperforator-transmitters on the receiving sides of which messages switched to this outlet are perforated for delivery to that line. The use of two machines in connection with an outgoing line materially cuts down the time this outlet will appear busy to incoming messages and also permits loading the line itself very close to its full capacity.

When the director determines that this outlet is the one on which the desired station is located, it tests the outgoing line circuit for the availability of the receiving side of one of its reperforator-transmitters.

If both machines are busy, the director circuit waits, maintaining its test until one of the machines becomes idle. As soon as one of the machines becomes idle the sending side of the reperforator-transmitter of the incoming line is connected to the receiving side of the outgoing line machine by means of the sequence circuit (5) and the crossbar switches of the link circuit (6). The use of the sequence circuit prevents more than one connection from being made through the crossbar switches during the brief period while the connection is being established, but simultaneous connections up to the capacity of the switches may exist at one time.

When connection is made from an incoming line circuit to an outgoing line circuit, this connection being known as a cross-office connection, the directing code and the message is reperforated in the machine of the outgoing line, and when the director reads the "Figures," *H*, "Letters" characters at the end of the message the cross-office connection is released.

The outgoing line circuit is arranged to deliver the traffic perforated in its two machines to the line on an alternate basis so that traffic delivered to one machine will not receive preference in transmission over that in the other. The stations, Figure 3, connected to a multi-

station line are equipped with a station control circuit, including a selector unit which is a motor-driven mechanical device for closing and locking a contact upon the reception of a number of characters received in a given sequential order. For example, a station is coded on a 2-character basis and to connect station (9) the characters *EF* must be received in that order.

When, therefore, the coding characters are sent to the line by the outgoing line circuit, the proper station is connected and the "Carriage Return," "Line Feed" signals, which precede the text of the message, will deactivate the selector units so that they will not respond to 2-character combinations in the message text that might connect other stations. The "Figures," *H*, "Letters" end characters will disconnect the station and reactivate the selector units. A station control circuit may control up to three receivers (8).

OUTGOING CONNECTIONS

If the traffic to a receiving station is very heavy, the same type of outgoing line circuit (10) is used, but the line is equipped with only one receiving station, and this station (1) does not require a station control circuit.

The system is not limited to one switching office but may have as many as desired. The number of switching offices is determined by a proper balance between the cost of switching equipment and the cost of lines. Messages received at a switching office are delivered to another switching office over trunks. The single outgoing trunk circuit (11) is arranged to deliver its traffic over a trunk to another switching point.

The traffic between switching offices may be heavy enough so that one trunk does not provide adequate capacity. In this case a multichannel trunk circuit which may have connected to it a minimum of two and maximum of ten trunks (12) is used. Reperforator-transmitters are not used in this case as the trunks themselves provide the required multiple switching paths. The speed of transmission over the trunk must be the same as the cross-office speed, 75 words a minute. Connection from incoming line to outgoing trunk is made on a first-idle-trunk basis.

LOCAL OUTLETS

Conditions arise in some installations where large volumes of traffic for the same destination must be delivered to points in the general locality of the switching office. The local outlet circuit is used for this purpose (13). These points may be equipped with ten receiving machines operating at cross-office speed directly from the inputs without reperforator-transmitters on the outlet side. The receivers are connected on a first-idle-receiver basis.

TRAFFIC FOR SWITCHING OFFICE

Some traffic received on incoming lines is destined for the switching office itself. The incoming line circuits can be equipped with a receiving-only teletypewriter in addition to the reperforator-transmitter (14). This traffic then can be switched directly to the receiving-only teletypewriter without burdening the switching mechanism of the office, thus increasing its over-all efficiency. Two specific codes are assigned for this use: a first character followed by *Z* which cuts on the receiving-only teletypewriter alone, or a first character followed by *H* which cuts on both the reperforator-transmitter and the receiving-only machine for reception of the message both at the switching office and some other station. When the volume of terminal traffic is not great enough to justify a receiving-only teletypewriter per incoming line, local outlet machines may be used.

SENDING FROM MULTISTATION LINES

In this discussion traffic was introduced into the system from a line equipped with only one station. It will be noted that all lines are full duplex permitting transmission both to and from stations on a line simultaneously.

Multistation lines may be equipped with up to ten sending stations as well as the ten receiving stations heretofore mentioned. Inasmuch as only one sending station may send at a given time, sending is controlled by a transmitter-start circuit (15) which is associated with the outgoing line. Each transmitter on the line is assigned a single-character transmitter-start code which, when sent over the line preceded by a specific pattern, causes the transmitter, if there is tape in it, to start sending.

Upon termination of sending from any station on a multistation line, the transmitter-start circuit (15) takes control of the outgoing line circuit and stops outgoing transmission. This stoppage may take place any time while the text of a message is being sent or between outgoing messages. A pattern is then sent out ("Blank," a pause, "Space") which cuts off the receivers connected to the line without mutilating the copy being received and conditions the station control circuits to control their transmitters. The transmitter-start circuit then sends the start character for the transmitter next in sequence. If this next station has traffic, transmission will begin and the receivers that were cut off will be restored. If it has no traffic the next transmitter in sequence will be tried and so on until either traffic has been found at some station or all have been tested without finding traffic. In the latter case the circuit waits for a predetermined interval, chosen to suit requirements, before it again starts to test stations for traffic.

Figure 3 (left). Typical station on a multistation line

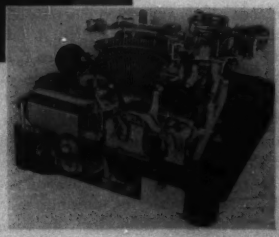

Figure 4 (right). Reperforator-transmitter

Each message in the tape at the sending station is terminated by "Figures," *H*, "Letters," which indicate the end of a message, but it may not be economical of line time to limit a transmission from a station to one message. The station operators are therefore instructed by the customer as to the maximum number of messages that may be included in a transmission. This number may be different for different stations depending on traffic needs. Following the "Figures," *H*, "Letters" characters of the last message two additional characters, *H* and "Letters," are perforated in the tape. These characters when registered in the incoming line circuit cause the transmitter-start circuit to test other sending stations on the line.

ORIGINATING STATION

For traffic originating at the switching office an automatic sending teletypewriter set is used (16) which is connected to an originating station circuit (17) and a director (18). The action of this director is the same as (4), except that it controls the sending set instead of a reperforator-transmitter.

MULTIPLE ADDRESS

Traffic consisting of messages introduced at a sending point to be delivered to many receiving stations in the system is handled by the multiple-address circuit.

When a sending operator prepares a message for delivery to a number of stations, a 2-character multiple-address code is first perforated in the tape. The operator then follows this specific multiple-address code by the codes of the stations of destination. There is no limitation upon the number of station codes that may be inserted. The multiple-address code instructs the director at the switching office involved to deliver the message to one of two reperforator-transmitters associated with the multiple-address circuit (19). The whole message, addresses and text, is perforated in one machine of the multiple-address circuit.

The multiple-address circuit is equipped with a special type of director which discards the multiple-address code and then starts reading the individual codes.

To show the operation of the equipment it may be assumed that the first code is for a station on the outgoing line (7). When the reading of the address by the multiple-address director indicates that this particular outlet is required, a bid is made to the outlet. If one of the outgoing line machines is idle, it is connected to the multiple-address circuit.

Connection of the outgoing line circuit to the multiple-address circuit causes the multiple-address director to send the code to the connected machine of the outlet and then, without disconnecting from it, to blind the transmission path. The second address is then read and connection to another outlet made in the same manner. If another address is for an outlet already connected, the transmission path is unblinded, the new address transmitted, and the transmission path again blinded. In like manner, all the addresses are read and the required outlets connected by means of a multiple transmission path.

If an address calls for transmission to another switching office, a trunk is connected. In connecting to a trunk, however, it is necessary to indicate to that trunk that this is a multiple-address message, so that it can be handled via the multiple-address message circuit in the next office. When, therefore, connection is made to a trunk for the first time, the multiple-address director inserts a multiple-address code ahead of the first address.

When all the addresses have been read and sent to the various outlets, the "Carriage Return," "Line Feed" signals preceding the text are read. This causes all the connected outlets to be unblinded and the text of the message to be sent to all outlets simultaneously. The "Figures," *H*, "Letters" characters following the message text release the connections.

GROUP CODE

Part of the multiple-address traffic of many customers includes many messages which are sent to the same group of stations as a matter of routine. Considerable saving in operating time and better accuracy is obtained by assigning each of these groups a single 2-character code. When such a code is encountered by the multiple-address director a group code circuit (20) is called into action which makes a simultaneous bid to all the outlets concerned. When all the outlets involved have been connected the multiple-address director sends the group code and the message to all these outlets.

SUPPLEMENTARY MULTIPLE ADDRESS

When the volume of multiple-address traffic is large, the capacity of the multiple-address circuit may be augmented by using the supplementary multiple-address circuit (21) which handles 2-, 3-, and 4-address messages.

When using the supplementary multiple-address circuit, specific multiple-address codes are assigned to 2-, 3-, and 4-address messages, and the regular directors connect the incoming sources to one of a maximum of five input levels of this supplementary circuit. A maximum of ten outputs, each equipped with a regular director and a reperforator-transmitter, may be provided.

If an input level is called into action by the 2-address code, it is informed that two outputs are required. When two outputs are connected, the first address is placed on the machine of the first and the second address on the machine of the second. The text of the message then is transmitted to both machines and the connection released. Thus the 2-address message has been broken into two single-address messages which are handled by the directors connected to the outputs in the same manner as does a director connected to an incoming line.

Similarly the 3- and 4-address messages are reproduced as three single- and four single-address messages.

INTERCEPTION

Different opening and closing times of stations due to time zone differences or shutdown of stations for holidays or maintenance make it desirable to have a means of intercepting messages bound for such a station or stations for later delivery. Such a device, the willful intercept circuit (22) which may have one or two receiving paths, is provided for the interception of single-address messages.

The operation of keys diverts the traffic to be intercepted to this circuit. At a later time, this traffic which is stored in a reperforator-transmitter can be re-entered into the system automatically by means of its associated director.

Multiple-address messages which use individual station codes are intercepted on typing reperforators by the multiple-address intercept circuit (24).

Another type of interception is necessary to take care of unassigned codes which may occur from errors on the part of the operators or troubles in transmission.

When an unassigned or mutilated code is encountered by either a regular or multiple-address director, a miscellaneous intercept circuit is called in (23), (24) which records the addresses and text on a typing reperforator. Any traffic recorded in this circuit has its addresses corrected by the switching office attendants and is re-entered into the system at an originating station.

GUARDS AGAINST MESSAGE LOSS AND DELAY

MESSAGE NUMBERING METHODS, such as point-to-point and channel numbering, have been used on teletypewriter systems for many years to discover system failures or troubles which have resulted in lost or delayed messages. Messages are not considered lost if they are delivered to a wrong point, as they can be rerouted. Neither numbering method provides for quick discovery of the loss or delay of a message, and in high-speed systems a message may be worthless if delayed more than a few minutes. Extra clerical work with its added opportunity for human errors and the consumption of valuable line time for number transmission are additional weaknesses of number checking methods.

If proper precautions are taken to guard against message loss and delay, the use of message numbering may be curtailed or entirely eliminated except as may be needed for message identification. With this in mind the *81C1* system was designed to include many safeguards against message loss as well as alarms to call the attention of operating personnel to trouble conditions quickly.

The substitution of one valid code for another at the head of a message by the operator will result in delivery to the wrong station from which point it can be rerouted.

The appearance of an invalid code at the head of a message, because of operator error or failure of machines or lines, when received at a switching office will direct the message to miscellaneous intercept with both an audible and visual alarm. If the invalid code appears on a multistation outgoing line, provision can be made so that the message will be typed on all receivers or on any master receiver selected for this purpose. An audible and visual alarm at the receivers then calls the operator's attention to the message.

If no end-of-transmission combination is received at the switching office from a multistation incoming line, an automatic end-of-transmission is registered after 45 seconds of idle line time.

An open line or trunk to the switching office is both audibly and visually alarmed at the switching office. An open outgoing multistation line is visually alarmed at each receiving station or at specific stations chosen for the purpose. Open single-station lines and loops to local outlets cause the receiving machine to run open.

Figure 5. Switching office of the General Motors Corporation in Detroit, Mich.

The failure of an incoming line reperforator-transmitter or receiving-only machine to respond to signals, tape failing to feed through the punch blocks, torn tape, and low tape supply are all audibly and visually alarmed at the switching office. Similar conditions on other teletypewriter apparatus at the switching office not only are alarmed but the machines also are automatically made busy to further messages until the condition is cleared.

Failure of the switching circuits to complete their functions as well as certain other improper functioning of these circuits causes an alarm to sound.

MAINTENANCE OF SERVICE

ALL CIRCUITS and machines utilized in this system are wired through plug connectors in order to allow the immediate replacement of a defective circuit or machine by a spare. A system of keys and lamps is provided at a control board. At this board lamps indicate traffic flow and stations sending on all circuits, keys provide for controlling the traffic flow as desired, and other lamps identify alarm conditions in individual circuits so that the quick diagnosis of trouble is greatly facilitated.

Each office is equipped with a testing unit to which nearly all circuits can be patched for test and at which all machines can be tested and repaired.

EQUIPMENT ARRANGEMENTS

FIGURE 5 shows the switching office at the General Motors Corporation in Detroit, Mich. The machine cabinets, each of which mounts two reperforator-transmitters, are shown at the right and in the rear of the middle row. These cabinets are of the unit type which facilitate installation and additions. At the extreme right behind the reperforator-transmitter cabinets are the cabinets which house the relay circuits for the various functions that have been described. These relay cabinets are manufactured as packages containing such combinations of circuit units that great flexibility as to the initial size of systems, as well as their expansion or contraction after they have been installed, is obtained.

At the left of the office are shown the originating stations, while in the front center appear the terminal traffic receiving-only teletypewriters which are associated with the incoming lines and the typing reperforators associated with the miscellaneous intercepts.

Instrumentation for Analysis of Contact Wear

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THE INSTRUMENTATION presented here was developed to measure the magnitude of some of the factors affecting contact wear, so that the effects of these factors may be evaluated. The ultimate goal is to be able to use these instruments to determine the contact life of a specific design in a few hours, instead of the usual weeks or months required for the life-testing methods now used.

A review of some of the factors affecting contact wear is necessary to understand the purpose of the measurements which these instruments are designed to make. For example, the major factors for bridging-type double-break contacts for a-c control are included in an empirical formula which approximates the life of the contact tips:

$$\frac{M}{N} = I^3[C_1 + C_2 K^3 t^3] \qquad (1)$$

where N is contact tip life; M is mass of contact material available for wear on the four contact tips; I is arc current

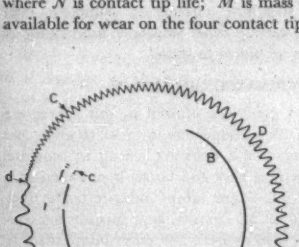

Figure 1. A-c contactor operating data. Trace *D* is time-displacement data for the magnet armature. Each cycle represents 0.00525-inch movement. Trace *B* is arc voltage representing contact bounce

during break; K is the ratio of the arc current during make to the arc current during break; t is milliseconds time duration of the arc during make; and C_1 and C_2 are constants. Some factors are implied in the constants, and some others were neglected, in deriving this equation.

A set of instruments has been developed to measure many of these variables. Basically, they consist of an oscilloscope and an arc time gauge. The arc time gauge measures total arcing time, t, in equation 1, during circuit make, and it may measure the d-c arcing time during circuit break. The polar-co-ordinate-type oscilloscope, together with its accessories, measures the following factors, one at a time: (1) The arc characteristic, as shown in Figure 1, trace *B*. (2) Instantaneous velocity of any moving part, as derived from complete time-displacement data. See Figure 1, trace *D*. (3) Vibration and shock characteristic and magnitude.

The oscilloscope measures arc characteristic by radial deflection of the spot in proportion to the voltage across the contacts, while the spot is sweeping circumferentially at a given constant speed. In Figure 1, trace *B*, the spot is moving counter-clockwise, with the direct 125-volt potential on the open contacts, causing the spot to be deflected off the face of the tube. Then, at *C*, the contact closes, and the voltage drops to nearly zero, but, as bounce occurs, an arc forms to give the spot a radial deflection proportional to the arc voltage. These first bounces are called primary bounce, or that caused by the kinetic energy of the moving contact bridge. At *S* another bounce occurs, caused by transfer of kinetic energy of the magnet (or moving parts other than the contact bridge) to the contact structure; this is called secondary bounce.

Instantaneous velocity is derived from a time-displacement curve which is plotted from the data of the oscillogram in Figure 1, trace *D*. Each cycle on the oscillogram represents a movement of 0.00525 inch.

The time-displacement oscillograms are obtained by attaching a lightweight film strip, having 190.4 parallel lines per linear inch, to the moving part, and moving this film strip over a similar stationary strip. A light source on one side of the film strips and a photoelectric tube on the other side result in one cycle of voltage output from the photoelectric tube amplifier circuit for each 0.00525-inch movement of the film strip. This voltage is applied to the oscilloscope input to produce the oscillogram.

Vibration is measured by applying the output of a standard vibration pickup to the input of the oscilloscope to produce a pattern of vibration amplitude versus time.

No calibration of the oscilloscope is necessary when making measurements of the arc characteristic or velocity. The circular sweep is driven by a 3-speed (900, 1,800, 3,600 rpm) synchronous motor. The spot then has a uniform angular velocity of 900, 1,800, or 3,600 rpm, and time measurements are made by measuring the angle of rotation.

The operation of the instruments is co-ordinated with the device under test so that data are automatically presented on each operation of the test device. The operator is free to observe and record data as desired.

While much work remains to be done before all of the factors affecting contact wear are defined and evaluated, it is well established that contact bounce is a major factor to be considered.

Digest of paper 51-52, "Instrumentation for Analysis of Contact Wear," recommended by the AIEE Committee on Industrial Control and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, January 22-26, 1951. Not scheduled for publication in AIEE *Transactions*.

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Lead-Alloy Power-Cable Sheath

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In a study of newly developed arsenical-lead alloys for sheathing of underground power cables, it has been found that these alloys are superior to copper-bearing alloys in the following aspects: withstanding bending caused by thermal expansion, resistance to creep caused by internal pressures, and life-to-fracture under tensile stress.

IN 1939 it was stated in an AIEE paper[1] that "for many cables the expected time of present-day commercial sheaths to cracking in manholes is only one-third to two-thirds of the life of the insulation" and that "better sheath materials are needed" to obtain a "balanced cable design." For over 20 years there has been an interest in the Commonwealth Edison Company in solving this problem.

The serviceability of cable insulations has been improved by changes in materials and factory processes. Proof was obtained[2] on the feasibility of operating the insulation at temperatures higher than those previously thought safe; and, for example, for various types of impregnated-paper-insulated lead-covered cables, permissible copper temperatures have been established for emergency operation which are from 10 to 30 degrees centigrade higher than those permitted for normal operation.

Until recent years, the rules for maximum allowable operating temperatures generally were applied to emergency loading when one line in a group feeding a given load was out of service. Since cable systems were built to avoid exceeding those limits, the normal loadings resulted usually in temperatures much below the allowable limits. With the establishment of emergency load ratings, the permissible daily normal loadings have increased considerably. (Obviously, this practice has resulted in sizable savings in plant investment costs for taking care of growing loads.)

With increased loads, the life of a given sheath to fracture decreases much faster than the rate of increase in amperes.[2] A major cause of the sheath breaks, which admit air and moisture into the insulation, is fatigue cracking resulting from daily movement of the cable due to longitudinal expansion and contraction with changes during the day in load on the lines. Such cracking occurs usually in the manholes where the cable movement causes slow bending, but sometimes it occurs in the ducts. It is especially troublesome on the larger cables.

Another cause of trouble is the expansion of the sheath due to internal pressure. The sheath expansion may be sufficient to impair the electrical strength of the insulation seriously, or may continue until the sheath ruptures. In either case, the result frequently has been either cable failure in service or replacement of the faulty cable before failure.

Essential text of paper 51-60, "Lead-Alloy Sheaths for Underground Power Cable," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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In solid-type cable, the internal pressure is produced during the heavy-load hours by thermal expansion of the oil in the cable, especially in those high-voltage cables having oil reservoirs connected at the joints, or having hydrostatic head in riser cables or cables on slopes. In more recent years, cables with controlled continuous positive pressure on oil or gas in the cable have come into use. In order to withstand the internal pressure sufficiently throughout the life of the cable, the sheathing must have both good resistance to expansion (very low rate of creep) and good elongation to fracture (ductility).

Increasing the conductor temperatures causes increases in sheath temperatures and in daily ranges in temperature. The resistance of lead and lead-alloy sheaths to fatigue cracking and to expansion by creep due to internal pressure decreases rapidly with increases in sheath temperature.

In order to utilize the possibilities of higher loading, there arose, therefore, a need for a sheathing material which would withstand both the slow bending of small amplitude and the internal pressures much better than commercially pure lead sheaths, and which would have other suitable properties. So far, such material has been found in the arsenical-lead alloys of which several are now in use. One type, which was described in an AIEE paper,[3] consists mainly of about 0.15 per cent arsenic, 0.10 per cent tin, and 0.10 per cent bismuth in lead. Other types contain much less bismuth and about 0.04 per cent copper. Following is a presentation of the principal results of investigations and tests of the arsenical-lead alloys and their application to the operation of underground power cables. In this discussion, commercially pure lead includes common desilverized lead *A*, chemical lead, and lead containing added copper.

LIFE-TO-FRACTURE IN BENDING

A DUMMY MANHOLE simulating a full-sized manhole in the streets was constructed in the laboratory.[1] Cable samples with a joint in the middle were installed in the manhole and moved in 70-second cycles, simulating the movement which occurs in service. Most of the tests were made with 0.5-inch movement of the cable at the duct mouth at each end of the manhole, which is a typical daily movement on a well-loaded 500,000-circular-mil 3-conductor 12-kv line in Chicago. On such cable the average temperature of the sheath in the manholes is about 110 degrees Fahrenheit (43 degrees centigrade) and in the ducts is higher.

The results of such tests for various cables have shown

Table I. Bend Tests to Fracture of the Sheath on 500,000-Circular-Mil 3-Conductor 12-Kv Cable in the Dummy Manhole

Temperature	Cycles to Fracture: Lead	Alloy
Room.....Belted cable.....	11,420(2)	35,471(3)
Room.....Shielded cable with metal binder.....	5,081(4)	17,943(1)
Room.....Shielded cable with paper binder.....	9,720(12)	22,564(3)
43°C.....Shielded cable with paper binder	2,755(2)	14,468(23)

Cable moved 0.5 inch at each end of manhole in 70-second cycles. The sheath thickness was 0.120 inch.
Figures in parentheses indicate number of tests.

that the number of cycles to fracture of arsenical-lead alloy sheaths is about three times that for lead sheaths under comparable conditions, and the ratio is sometimes greater. Data for one cable size are shown in Table I.

The type of construction of the cable exerts a considerable influence on the life-to-fracture of the sheath. If 3-conductor cable has a copper shielding tape over the insulation on each conductor and a copper or bronze tape with an intercalated-paper tape wrapped around all three insulated conductors to bind them together—the common construction of shielded cable—then the life-to-fracture of the lead sheath in bending is about half that of sheath on belted-type cable. The metal tape wrapped around the cable has some rigidity and tends to concentrate the working of the sheath over the edges of the metal tape. If the shielded cable has three or four paper tapes (total about 20 mils thick) instead of the metal and paper-tape binder, then the life of the sheath in bending is better, but is still less than that of the sheath on belted cable. However, the alloy sheath on the shielded cable with paper binder has been found to have over twice the life-to-fracture of the lead sheath on belted cable. The shielded-type of cable has some advantages in stability of the insulation under voltage and somewhat greater current-carrying capacity than belted cable with the same conductor size, and so there is a general trend toward use of the shielded type for cables rated above 8 kv. Some users specify paper-tape binders.

Figure 1 shows the results of bend tests of one cable design with alloy sheath with various movements at each duct mouth. Most of the tests represented in these data were made on 25-foot samples in the dummy manhole apparatus with an offset of 19 inches between the centers of the cable in the duct and in the joint. Some of them were made on 8-foot samples of cable bent into U shape, held at one end, and moved back and forth at the other end. With the motion adjusted to give the same maximum strain of the sheath in this test as in the dummy manhole, the resulting number of cycles to fracture of the sheath has been found to be about the same as in the dummy manhole apparatus.

These results indicate that at 43 degrees centigrade with 0.32-per cent sheath strain (equivalent to 1/2-inch movement of this cable at each end of the manhole), the average life-to-fracture at a speed of about one cycle per minute is about 14,000 cycles for arsenical-lead sheath. The 1/2-inch movement corresponds to a daily range in conductor temperature of about 25 degrees centigrade on sections of that cable longer than about 300 feet. These data relating movement to life-to-fracture of the sheath provide a means of predicting the service life of the sheath for various current loadings of the line.

In commercial operation the bending cycle is generally a 24-hour cycle. In order to obtain an indication of the effect of slower movement than the 70-second cycles used in the dummy manhole on the number of cycles to produce fracture of the sheath, bend tests were made on strips cut from cable sheaths,[4] with 1-minute, 10-minute, and 60-minute cycles. The number of test results obtained to date is inadequate to establish definitely the relation between speed of bending and number of cycles to fracture. However, as is shown in Figure 2, extrapolation from the available test results indicates that the number of 1-day cycles to produce fracture is roughly one-third of the number with 1-minute cycles. Since the action within the structure of the metal is somewhat different in a strip of sheath when bent than it is in a sheath on a cable, the results of these tests can be applied in only an approximate manner to service conditions. The data indicate then that the life-to-fracture of the alloy sheath on a well-loaded 12-kv line is about one-third of 14,000 cycles, or about 5,000 cycles. This corresponds to an indicated life-to-fracture of the sheath in the manhole of about 16 years.

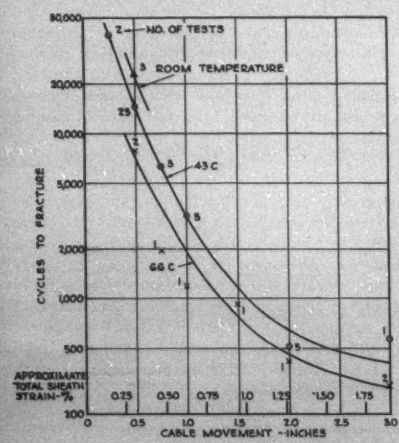

Figure 1 (left). Bend tests of 500,000-circular-mil 3-conductor 12-kv shielded cable with lead-alloy sheath

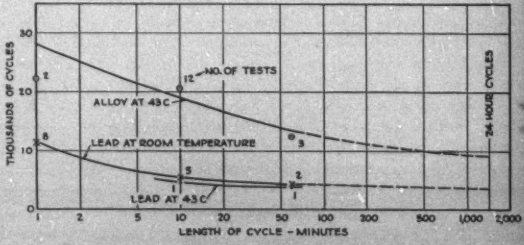

Figure 2 (above). Bend tests of strips at 0.3-per cent strain

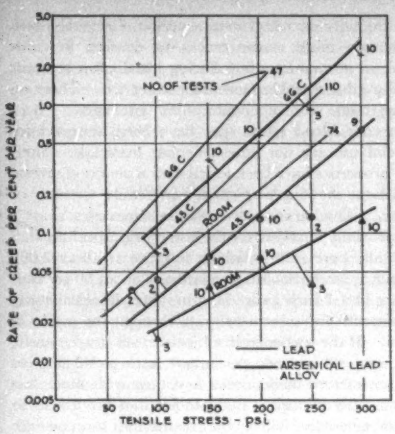

Figure 3 (left). Creep rate of strips

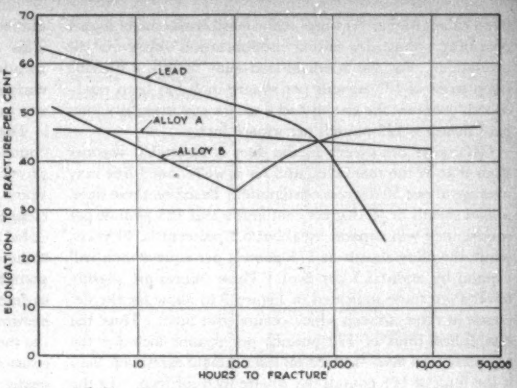

Figure 4 (above). Typical trends in ductility at 43 degrees centigrade

If the line is not regularly well loaded, as is generally the case, so that the average daily cable movement is only 1/4 inch, for example, then at the same temperature the sheath will fracture in about 40,000 cycles in the laboratory test, or more than 40 years in commercial service. Furthermore, with less load the sheath temperature in the manhole would be somewhat less than 110 degrees Fahrenheit (43 degrees centigrade) and the life-to-fracture would be even longer.

During emergencies, the cable occasionally might be more heavily loaded for a day or two, with the result that the cable movement might be as much as two inches at each end of the manhole. If the cable is in a well-loaded duct bank, the sheath temperature in the manhole may be about 150 degrees Fahrenheit (66 degrees centigrade). For such conditions, the indicated life-to-fracture on test is only 500 cycles, and in service is, perhaps, one-third of that or 170 cycles. However, one or two load cycles under such conditions would consume only about one per cent of the life of the sheath, which is a negligible part of the service life.

These bend tests have shown that the lead-alloy sheath has a life-to-fracture at 1-inch cable movement about equal to that of lead sheath at 0.50-inch movement. Data have been presented[2] relating cycles of movement to produce fracture to daily range in temperature. Based on those data, this increase in allowable movement corresponds to an increase in daily temperature range of about 50 per cent. Thus, for equal sheath life, the alloy permits about 22 per cent higher current loading of the cable.

RESISTANCE TO CREEP

Arsenical-lead alloys are also markedly superior to lead in the ability to withstand stress, as indicated by rates of creep. The average results of a large number of tests of strip specimens under steady tensile stress[5] are shown in Figure 3. The results shown for alloy lead were obtained on the approved types. At temperatures between room temperature and 43 degrees centigrade, and at the stresses which are most common for cable sheaths in service, the alloys take about 100 pounds per square inch higher stress than lead to produce a given rate of creep. At 66 degrees centigrade, the difference in stress is about 60 to 80 pounds per square inch. Thus, though the advantage of the alloy is not so great at unusually warm locations or during emergency operation, the difference is considerable.

These creep rates are based on the elongation of strip specimens under steady tensile stress between 1,000 and 2,000 hours of testing. Most of the tests on strips were run to 5,000 hours, but some were continued to as long as five years. Generally, after 2,000 hours the rate of creep under normal conditions of temperature and stress decreases slowly for a long period until finally a rising rate leading to failure develops. The decreasing trend occurs for both lead and the arsenical-lead alloys. Thus, the rates of creep shown in Figure 3 are a little higher than they would be for periods of years in service.

The strip specimens used in these creep tests were 1/4-inch wide in the gauge section. An investigation was deemed necessary to determine whether the results could be applied directly to the sheath on cable with internal pressure. Samples of sheathing six feet long with sealed ends were filled with oil and were maintained with internal pressure at room temperature for some samples and at 66 degrees centigrade for others. The rates of radial expansion of these sheaths over long periods of time (one test ran 13 years until the sheath split) were compared with the rates of elongation of the strip specimens of the same materials. In most cases, the rates of creep for long periods of time were practically the same for both the strip and cylindrical samples, but in some cases the rates for the latter were lower. The rates of creep shown in Figure 3 are, therefore, conservatively on the high side.

Good creep resistance is especially important for cables which are maintained with internal pressure. For oil-filled cable, the ability of the sheath to withstand higher internal pressures makes possible savings in the provisions of oil reservoirs for the thermal expansion of the oil. For gas-

filled cable, higher pressures make feasible the use of higher operating voltage by raising the ionization voltage of the insulation. For the arsenical-lead-alloy sheath, a limiting hoop stress of 175 pounds per square inch has been established,[6] whereas the established limit for commercially pure lead sheath is 125 pounds per square inch.

Generally, the sheath in the duct is somewhat warmer than that in the manholes, and for a well-loaded line may average about 50 degrees centigrade. Based on these data, a lead sheath at 50 degrees centigrade and 125 pounds per square inch will expand by about 6.1 per cent in 40 years, while the alloy sheath at 175 pounds per square inch will expand by about 5.5 per cent. These figures are slightly lower than those indicated in Figure 3 to allow for the decrease in rates of creep which occurs with time. Thus, the established limit of 175 pounds per square inch for the arsenical-lead alloy is based on less ultimate expansion than is the limit of 125 pounds per square inch for lead. In the following section the alloy is shown to be much better able than lead to withstand such expansion.

LONG-TIME EFFECTS

Commercially pure lead does not harden with age. In fact, it will recrystallize quite readily under ordinary service conditions of temperature and stress. The tensile strength and hardness show little or no change with time, but elongation to fracture decreases in a very long time under stress.

Small amounts of some alloying substances can make lead an age-hardening metal so that the tensile strength increases and the ductility decreases over a period of several years. This decrease might cause cracks to develop in cable sheathing in normal handling during installation or cause early failure due to cable movement in service. These remarks are in line with experience of ten years ago.

The arsenical-lead alloys that have been accepted for commercial use are not age-hardening materials. Their physical properties have been tested over a period of several years without showing any change in tensile strength or elongation. The hardness decreases in some cases.

In short-time tensile-strength tests, strip specimens of commercially pure lead sheathing fracture at about 2,000 pounds per square inch with elongation of about 50 per cent to fracture in a 2-inch gauge length. Metallurgical study shows that such fractures usually go through the grains of the metal. If the specimen is subjected to a steady tensile stress of, say, 500 pounds per square inch at 43 degrees centigrade, fracture might occur in a year with much less elongation. Metallurgical study shows that the cracks in such tests generally follow the boundaries around the grains. Thus, the nature of fracture of sheaths in service appears to be somewhat different from that in short-time tests, and depends more on the strength of the metal in the grain-boundary region.

Lead cable sheaths in service with internal pressure have been found to burst open when the diameters have increased by as little as $3\frac{1}{2}$ or 4 per cent. These sheaths were fairly uniform in thickness around the circumference. Therefore, the dependable life of such sheathing can be considered to be ended when expansion of about that amount is reached.

The arsenical-lead-alloy sheaths have been found to have good ductility in long-time tests. Some typical test results are shown in Figure 4. In some cases, such as alloy *A*, the elongation to fracture remains almost unchanged in tests to over a year. In other cases, such as alloy *B*, there is a decline in ductility at first and then for tests of longer duration, higher values are shown. It appears that over long periods of time in service these alloys can be depended upon to expand by at least 10 per cent before fracture occurs. This is more than enough for most practical purposes. The ability of the sheath to expand without bursting is of value for solid-type cable in which oil is fed to the cable from reservoirs connected to the joints or from terminals or for cables installed vertically or on steep slopes where the hydrostatic head of oil creates internal pressure at the bottom. It is of value, also, for pressure-type cables such as low-pressure oil-filled cable and gas-filled cable.

Figure 5 shows the relation between stress and time to fracture in tests of strip specimens at 43 degrees centigrade with steady tensile stress. In addition, a few tests on sheaths at stresses of 200 to 315 pounds per square inch, some to fracture in as long as 13 years, have been made on cable samples with internal pressure, and the results have been generally in line with the relations shown on the figure. These data show that to produce fracture in 100 hours, for example, the alloy sheath requires about 400 pounds per square inch greater stress than does copper-bearing lead sheath. The difference between alloy and lead decreases for longer tests at lower stresses. If these

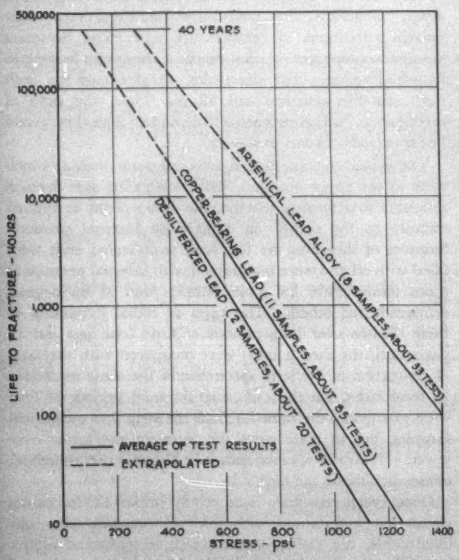

Figure 5. Life-to-fracture of strips under steady tensile stress at 43 degrees centigrade

data are extrapolated to 40-year life, then the indication is that the average stress to produce fracture of the alloy sheath is about 280 pounds per square inch, and that for copper-bearing lead sheath is about 90 pounds per square inch. While such extrapolation is only approximate, the data furnish definite evidence of the marked superiority of the arsenical-lead alloy.

INSTALLATION OF CABLE

Since arsenical-lead-alloy sheath is somewhat harder and stronger than lead sheath, it is somewhat better able to resist scoring or abrasion when the cable is pulled into the duct. This feature is especially of value for the large and heavy cables. Also, the higher tensile strength of the alloy sheath is of some advantage in withstanding the forces to pull the cable into the duct.

Slightly greater force is required to bend the cable to train it into position in the manholes. However, alloy-sheathed cables with large conductors having over-all diameters of 3.0, 3.3, and even 3.4 inches, have been installed in 4-inch ducts in 600- to 700-foot lengths without any substantial difficulty. For cables smaller than 3.0 inches, the difference in handling has not been noticeable.

In a few cases, cracks have developed during installation of some of the early alloy sheaths, mainly on cables having diameters about 3.3 inches. Those sheaths were found to be abnormally hard and low in ductility in the region of the fractures. This condition was due to improper conditions of extrusion of the sheath at the factory. Investigations have shown that, in order to avoid such troubles and to obtain uniformly good properties of the alloy, close control of the treatment of the metal, both in the lead press and after it leaves the lead press, is necessary. The methods and control of the extrusion process have been improved.

The lead alloy-sheath withstands vibration much better[3] than does lead sheath. This is of interest for installation, particularly on bridges and on aerial messenger wire.

Beginning in 1944, the Commonwealth Edison Company adopted the arsenical-lead alloys for sheathing on 4- and 12-kv 3-conductor cables of the larger sizes (375,000 circular mils and larger) and on all 66- and 132-kv cables. Cable with these alloys has been furnished by six manufacturers. Some of the manufacturers are continuing their development work on various lead-alloy sheaths. The tests described here are also continuing.

POSSIBLE CHANGES IN CONSTRUCTION

Since the arsenical-lead alloy is considerably better than lead in the important characteristics for power-cable sheathing, could not the change from lead to alloy sheath be accompanied by a reduction in sheath thickness with a corresponding reduction in the cost of the cable? Bend tests were made on 12-kv cable having alloy sheaths 65 mils, 85 mils, and 100 mils thick in addition to the standard thickness of 120 mils. The results indicated reduction in life-to-fracture equal to or slightly greater than the percentage reduction in thickness. See Figure 6. Where this property is not the controlling factor in the service life of the cable, the thickness might be reduced by about 10 per cent. With the corresponding reduction in life, the alloy sheath would still have an appreciable advantage in this respect compared with lead sheath.

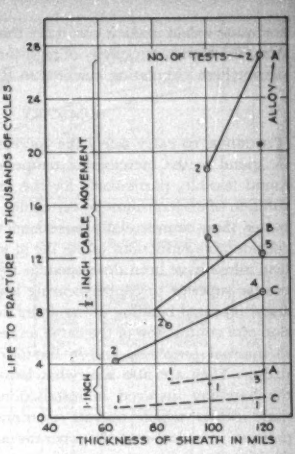

Figure 6. Bend tests of 12-kv cable with alloy sheath of various thicknesses at 43 degrees centigrade

Some bend tests were made of cable with 85-mil alloy sheath and 75-mil fabric-reinforced neoprene jacket and of cable with 65-mil alloy sheath and 90-mil extruded polyethylene jacket. Difficulties were encountered in determining when the sheath under the jacket had cracked. However, according to the test indications, while the jacket is new and tight on the sheath, it is of benefit in lengthening the life-to-fracture if the repeated bending strains are large enough to produce appreciable wrinkling or buckling of the sheath of reduced thickness without jacket. With age in service, however, the jacket might loosen on the cable and become of little or no help to the sheath. The use of a jacket, of course, practically eliminates the possibility of scoring of the sheath during installation. Such scoring might reduce its thickness at places by as much as 15 per cent. Based on this consideration mainly, the commonly used specifications[6] for oil-filled cable were recently revised to permit a one-sixth reduction in sheath thickness when jackets are applied over the sheaths.

Alloy sheath as thin as 65 mils on cable of this size would be relatively weak to withstand the pulling forces involved in installing the cable. It would have a tendency to wrinkle when the cable was bent. It would require considerable care to make solder wipes on such thin sheath for joints and potheads. With the addition of a jacket over the sheath, it would make little or no saving in the factory cost of the cable compared to 120-mil alloy-lead sheath.

Some consideration has been given to the possible use of materials other than lead or lead alloy for power cable sheaths. While some of the synthetic materials which are now commercially available have very good resistance to moisture, none of them will keep out water completely as lead sheath does. Aluminum sheath would be lighter than lead sheath and could withstand higher internal pressures. The latter is of interest for high-pressure cables. For use underground, however, the necessary covering to prevent

corrosion would make it cost more than lead-covered cable. Also, the high conductivity of high-purity aluminum would permit high circulating currents in the sheath.

SUMMARY

IN ORDER TO carry safely the increased loads that correspond to the increases in temperatures that have been found feasible, particularly for the impregnated-paper insulation of underground power cables, a sheathing material better than commercially pure lead was needed to avoid considerable reductions in the life of the cable. Arsenical-lead alloys have been developed to meet this need. They are far superior to copper-bearing lead in ability to withstand repeated bending in manholes due to thermal expansion and contraction of the cable, in resistance to creep due to internal pressures, and in life-to-fracture under tensile stress. They are also somewhat better able to withstand the handling involved in installation of the cable. For some cables which operate continuously with internal pressure, arsenical-lead alloys permit use of a sheath without additional reinforcing covering.

The improved ability to withstand bending makes feasible the use of less offset in the manholes between the center of the cable in the duct and in the joint. Thus, existing manholes can sometimes be used for the installation of an alloy-sheathed cable, where for the same cable having a commercially-pure lead sheath enlargement of the manhole would be necessary to provide the necessary large offsets. For new manholes, a reduction in offset permits a reduction in the cost of the manhole. Development work on arsenical-lead alloys is continuing and some cable manufacturers are searching for other suitable lead alloys.

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High Saturation Magnetic Alloy with a Rectangular Hysteresis Loop

J. F. LIBSCH EBERHARD BOTH

A study has been made of magnetic alloys which have a nearly rectangular hysteresis loop. This characteristic is desirable for materials used in saturable reactors, magnetic amplifiers, pulse transformers, and other nonlinear circuit elements.

THE PERFORMANCE of saturable reactors, magnetic amplifiers, pulse transformers, and other nonlinear circuit elements depends largely on the characteristics of the magnetic core material used. Generally speaking, for these applications the most desirable flux-versus-field-strength relationship is depicted by a rectangular hysteresis loop, preferably with a high saturation and a low coercive force value. Of the commercial magnetic materials, the grain-oriented 50-per cent nickel-iron alloys known as Deltamax, Hipernik V, Orthonik, and Permeron possess the most valuable combination of mechanical and magnetic properties required by nonlinear electrical components.

The saturation value of this material is about 15,000 gausses. This is relatively high and quite satisfactory for numerous applications. Still higher operating flux density values, however, are dictated by the general trend towards reduction of size and weight of electric equipment, especially for military field use. Therefore, the authors and their associates[1] have been studying the possibility of imparting rectangular hysteresis characteristics to alloys containing 30- to 50-per cent cobalt and the remainder iron, that is, those materials which have the highest saturation values of all.

The rectangular hysteresis loop or, stated differently, the almost complete flux reversal at a field strength closely equal to the coercive force, results from the proper alignment of the magnetic domains in such a way as to eliminate all rotational magnetization processes. Processes known to achieve this alignment under certain conditions are mechanical stresses, grain orientation, and heat treatments in a magnetic field. The latter technique has been used exclusively in this study.

All specimens were prepared by powder metallurgy.

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Table I. Comparison of Cobalt-Iron and Nickel-Iron Rectangular Hysteresis Characteristics

	50% Co–50% Fe	50% Ni–50% Fe[1]
Saturation induction, B_s in gausses	22,400 (H=100)	15,000 (H=12.5)
Retentivity, B_r in gausses	19,000	14,500
Coercive force, H_c in oersteds	0.68	0.10
Rectangularity, B_r/B_s in per cent	85	96.5

Originally this method was chosen since it affords the possibility of excluding from the alloys to be studied such elements as manganese, silicon, or vanadium, which are being added to conventionally produced materials for reasons of workability. A further advantage of the powder metallurgy technique is its convenience in covering a rather large number of compositions with a minimum amount of material and at low cost. It appears that these merits could well be utilized in the production of cobalt-iron or other magnetic material in the form of special finished parts.

In fabricating the specimens, the elemental powders were mixed, pressed to toroidal shape in a die, sintered at 1,400 degrees centigrade in pure dry hydrogen, and, following a test of the magnetic properties in this state, subjected to cooling in a magnetic field of 20 oersteds from a temperature of 1,020 degrees centigrade.

Figure 1 shows the saturation induction B_s, the retentivity B_r, and the coercive force H_c of high-saturation cobalt-iron alloys containing 30 to 55 per cent of cobalt

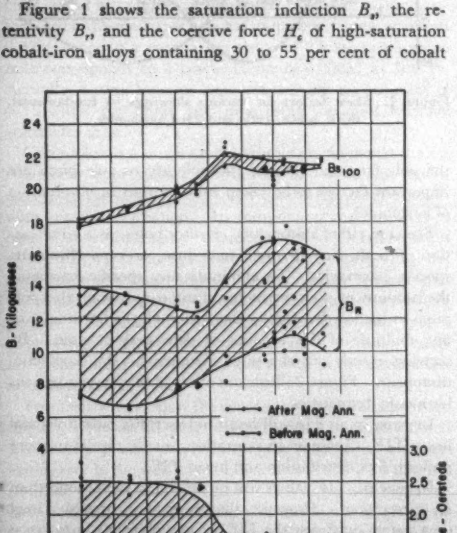

Figure 1. Effect of magnetic anneal on the magnetic properties of iron-cobalt alloys

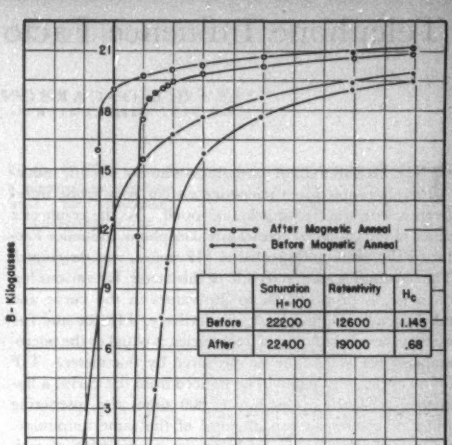

Figure 2. D-c hysteresis loops and magnetic properties of 50-per cent iron–50-per cent cobalt alloy made from high-purity cobalt powder, before and after magnetic annealing

in both the sintered and the magnetically annealed condition. All alloys in this range are found to respond to the magnetic anneal by an increase of B_r and a decrease of H_c. A rather sharply limited optimum of this response occurs close to the 50-per cent cobalt–50-per cent iron composition.

Figure 2 shows d-c hysteresis loops of the best sample of this composition obtained. Its properties also are compared with published values of the grain-oriented 50-per cent nickel-iron in Table I. With regard to rectangularity of the hysteresis loop as expressed by the B_r/B_s value, and with regard to the coercive force, the properties of the cobalt-iron alloy fall short of those of the nickel-iron alloy. It appears noteworthy, however, that its absolute retentivity value surpasses that of nickel-iron by more than 4,000 gausses.

Cobalt-iron alloys, especially those containing about 50-per cent iron and 50-per cent cobalt, respond to a magnetic annealing treatment by a marked change in the shape of their hysteresis loop. Although the B_r/B_s ratio and the coercive force of this alloy are inferior to the respective values of the grain-oriented 50-per cent nickel-iron alloy, the combination of higher absolute saturation and retentivity values may prove helpful for certain applications.

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Telephone Influence Factor in Synchronous Machines

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THE PRESENCE of harmonics in an a-c circuit, inductively coupled to a telephone system, may cause interference with the transmission of sound. As the result of a series of tests, a meter to measure Telephone Influence Factor (TIF), commonly called a TIF meter, was developed. The admittance characteristic of this meter, for various frequencies, is proportional to the values in the curve and tabulation in Figure 1. Quantitatively, TIF for any frequency, or combination of frequencies, is equal to the microamperes per volt input, as measured by this meter. TIF for 60 cycles is 1. As will be noticed from the curve, a frequency of 1,070 cycles has 12,000 times the interfering effect of a 60-cycle fundamental of the same amplitude. By use of a harmonic analyzer, the contribution of each component to the total TIF may be determined.

Harmonics in a-c power circuits usually result from characteristics of synchronous machines on that circuit. However, induction motors have also introduced appreciable interfering harmonics.

In designing synchronous machines, the following factors affect TIF: stator slotting; armature coil pitch; number of coils and turns per coil; angular span of phase belts; skew of stator slots, or rotor poles, or both; pole arc and shape; air gap and relation of slot width to slot pitch; and saturation in magnetic circuits.

Stator slotting introduces harmonics which are equal to $2(S/P \pm 1)f$ where S/P is the slots per pole and f is the fundamental frequency.

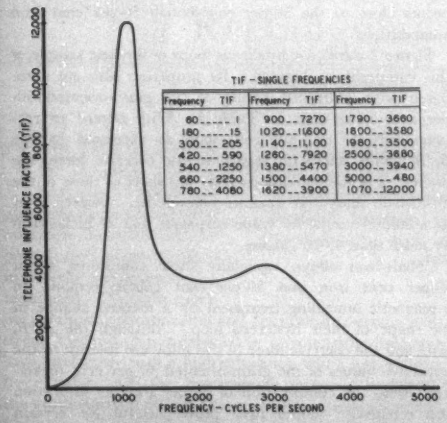

Figure 1. Frequency weighting for Telephone Influence Factor measurements

Fractional slotting can be used to increase the value of S/P and thus the frequency of the resulting harmonics to a point where the interfering effect is greatly reduced. Chording can be used to reduce or eliminate certain harmonics. If the pitch of the stator coils is two-thirds of full pitch, all odd triple harmonics are eliminated. Shape of

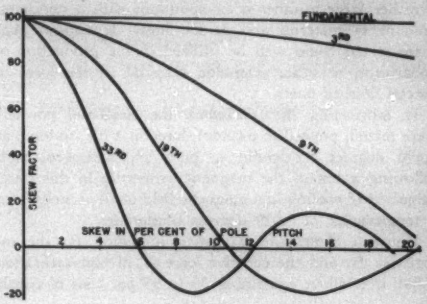

Figure 2. Skew factors for various skewings on fundamental, third, ninth, 19th, and 23rd harmonics

the pole face and ratio of the pole arc to pole pitch are important factors to be taken into account in elimination of harmonics.

Skewing either stator slots, or rotor poles, or a combination of both may be used to reduce, or even eliminate, specific harmonics. To eliminate any specific harmonic the amount of skew in inches must equal twice the pole pitch in inches divided by the order of the harmonic, or any multiple of this amount of skew may be used. By skewing exactly one slot pitch distance, all slot harmonics disappear. Figure 2 illustrates effect of skewing on various harmonic frequencies.

Increase in air gap will result in lesser flux pulsations and lower TIF. Increase in saturation usually results in more uniform flux distribution and lower TIF.

In general, TIF values will be much less under load than on open circuit. However, the presence of capacitive load on a system may raise the TIF because of its low impedance to high frequencies. A series of voltage transformations will reduce amplitude of harmonics and thus reduce TIF, although highly saturated transformers may introduce third harmonics into the system.

Digest of paper 51-124, "Telephone Influence Factor in Synchronous Machines," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Techniques of Corona Loss Measurement and Analysis

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THIS ARTICLE discusses the test equipment which has been added to the test facilities of the 500-kv experimental lines, the verification of the accuracy of the corona loss instrumentation, and the techniques of analysis and reduction of data which have been developed.

Three 3-phase lines, two 1.4 miles long and one 800 feet long, are energized by a 5,000-kva bank of three 500-kv single-phase transformers. The transformers were built as conventional power transformers using the form-fit tank with shell-form construction. The corona loss instrumentation is mounted on top of the high-voltage bushings. Provision is made for observing or recording the loss on each test conductor simultaneously. The instruments are read through a telescope mounted in an observation booth which is about 50 feet away.

A corona loss measuring circuit must operate at very low power factors. It is therefore extremely sensitive to small phase-angle errors which in more ordinary metering circuits would go completely unnoticed. By way of comparison, an ordinary capacitor has a power factor of about 0.0026, whereas a corona loss value of 0.5 kw per 3-phase mile corresponds to a power factor of 0.00037 at 500 kv. Actually, corona loss can be measured with an accuracy of ±15 watts per phase per mile using the most sensitive wattmeter scale.

Corona loss is a much more variable phenomenon than is commonly appreciated. Variations of ten to one under ostensibly the same weather and conductor surface conditions are not uncommon. In addition, corona is subject to both a "short-time aging" characteristic, which is a function of the history of energization immediately preceding the application of voltage, and a "long-time aging" characteristic, which is the cumulative effect of energization over long periods. These factors make successive tests vary over a large range. Before these phenomena were fully recognized they were attributed to instability in the corona loss instrumentation circuit.

From early tests below the corona threshold voltage, when the test lines, for all practical purposes, can be considered a capacitor of zero power factor, the presence of a phase-angle error in the wattmeter indications of about 18 minutes (0.00528 radian) was suspected. This angle was measured independently by temporarily substituting a single-phase high-voltage capacitor for one of the long-line test conductors. This capacitor, Figure 1, was made up of Type-*3D* 15-kva 7,960-volt capacitors connected in series, and its capacitance was approximately equal to that of the test conductor. By comparing the readings of the wattmeters with the known losses of this capacitor, the phase-angle error was found to be constant. Therefore it could be corrected by placing a reactor in the voltage-coil circuit.

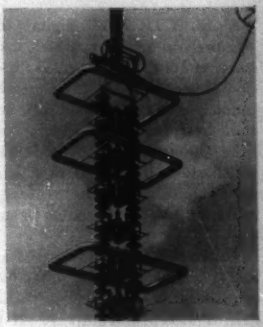

Figure 1. Top units of a high-voltage capacitor used for measuring phase-angle error

The principal source of this error was found to be the compact design and heavy shielding of the wattmeters, necessitated by the limited space available in the instrument cabinets.

A method of analysis was developed which permitted measurement of extremely small phase angles very accurately. This revealed a small variable phase-angle error which is a function of transformer tap position. This variation is caused by changes in the leakage flux in the transformer causing a change in the eddy and stray losses. The magnitude of this variation for all possible tap combinations has been determined, and corrections are applied.

A unique weather instrument, to record primarily fog and rain too light to be detected by a conventional rain gauge, has been developed. This consists of a movie camera which takes a weather picture every 20 minutes.

Provision is made to heat one of the test conductors artificially so that the effect of conductor temperature can be evaluated. A setup for recording the loss on a horizontal and on a vertical insulator string alternately for periods of 20 minutes each has been installed. A graphic voltage gradient meter for recording the voltage gradient at the earth's surface is available. A technique for converting data obtained with various test configurations and under different fair-weather conditions has been developed. This has been extended to give a method for converting single-phase data to 3-phase values.

Simultaneous records of corona-loss on nine different conductors, and of several weather parameters were taken. This information is correlated and reduced in several ways in order to make the data useful in the design of future extra-high-voltage transmission lines.

Digest of paper 51-80, "Techniques of Corona Loss Measurement and Analysis—500-Kv Test Project of the American Gas and Electric Company," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A Method of Gating for Parallel Computers

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IN ELECTRONIC digital computers information is stored in registers, which consist of a number of bistable circuits, usually called flip-flops. During the operation of the computer it frequently is necessary to transfer the information from one register to another. In parallel computers the information is transferred simultaneously from all flip-flops along parallel routes. The apparatus which causes the second, or slave register, to be set according to the first, or master register, is called a gate, and the operation is that of reading or gating the master into the slave.

Registers frequently contain as many as 40 flip-flops, and it is highly desirable that the gates be as simple and economical of equipment as possible. The gate described here is shown in Figure 1. It uses but two diodes per flip-flop, coupling the plates of each master to the grids of the corresponding slave. Two additional tubes are required to pulse the common plate supply of all the master flip-flops.

Normally, E_1 and E_2 have the value E, and the two registers are independent since both slave grids are at lower potentials than either master plate. When it is desired to set the slave to agree with the master, the voltage E_1 is

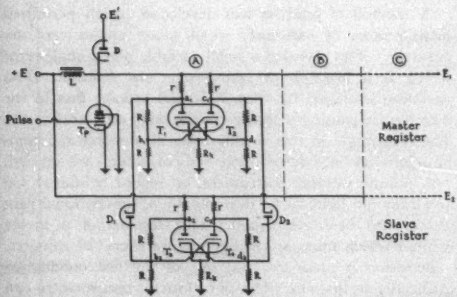

Figure 1. One flip-flop of each register showing the gating diodes and the common pulsing pentode

lowered momentarily, thereby directly coupling the two flip-flops so that the state of the slave is determined by that of the master.

To understand the gating operation, consider a particular case in which the tubes T_1 and T_4 are conducting before E_1 is reduced. Then the point a_1 is lower in potential than c_1 and d_2 is lower than b_2. If E_1 decreases sufficiently the plate (a_1) potential of T_1 falls below the grid (b_2) potential of T_4, causing the diode D_1 to conduct and thus lowering the grid potential of T_4. This decreases the plate current of T_4, thereby increasing the grid (d_2) potential and decreasing the cathode potential of T_2. If these two changes are sufficient to cause T_2 to conduct while the diode D_2 is still not conducting (a matter of design), the slave flip-flop changes its state and agrees with the master.

If, on the other hand, T_2 had been the conducting tube originally, neither diode would have conducted and therefore no change of state would have occurred.

Further, if E_1 be reduced so far that both diodes conduct, the slave will, if necessary, reverse as E_1 falls and will not be further disturbed as E_1 rises again if the resistors are properly chosen.

By reconnecting the diodes the roles of master and slave are interchanged, and by using two pairs of diodes the operation becomes bilateral; either register may be read into the other.

Furthermore, it is possible to use one set of diodes to couple the master flip-flops to slave flip-flops removed any number of places to right or left. The other set of diodes then can be used to return the information so shifted to the master registers, and the apparatus becomes a simple, fast, shifting mechanism.

The time required to transfer a number depends upon the time it takes to reduce E_1 sufficiently. By pulsing E_1 very hard and limiting its minimum value by a supporting diode D, the whole operation can be made to take considerably less than one microsecond for a 48-digit register. The pulse magnitude and duration must be sufficient for the gates to operate. The pulse shape is otherwise unimportant.

Experiment confirmed the satisfactory behaviour expected of this circuit, even when the parameters were deliberately chosen near their limiting values.

There are several relationships among the parameters which must be satisfied if reliable operation is to be obtained, but none of them is difficult to meet in designing the circuit. The circuit described meets all basic requirements of a satisfactory gate for parallel computers. It can be made fast: speeds of one-half to one microsecond are easily obtained. Little extra apparatus is required and only diodes are used. The gating operation is done by direct coupling, making the gating wave shape relatively unimportant.

The principle underlying this gate is applicable to other types of computer circuits than that shown in Figure 1, and has been so used, successfully, with a great saving in equipment.

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Power Supplies and Rectifiers for Electric Railways in Providence

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A study of the power supply to the United Electric Railways was initiated when new construction necessitated the relocation of rotary converters. The question of replacement with more modern equipment and feeder and trolley system losses was studied by the use of probability methods.

THE UNITED Electric Railways (UER) provide transportation for over 500,000 people in Providence and adjacent cities and towns in Rhode Island. The operation of the transportation system which includes both electrically- and gas-driven vehicles, has been described in an earlier paper.[1] This article is concerned only with the power supply to the electric vehicles. At the time of this study there were 12 trolley bus routes and five street-car lines using 205 buses and 93 cars. Since then, the trolley cars have been replaced by trolley buses.

The overhead trolley system was supplied at 600 volts d-c from five Narragansett Electric Company substations. Figure 1 shows the geographical location of the trolley feeders and the substations. Except for a 4-kv 60-cycle rectifier installation at Elmwood, the others, Manchester Street, North Main Street, Fountain Street, and Olneyville, were equipped with rotary converters supplied at 11 kv and 25 cycles from the Manchester Street Steam Station.

When an expansion program at this steam plant made it necessary to remove the four 40-year-old rotary converters located there, the question of replacement with more modern 60-cycle equipment was considered in conjunction with a comprehensive study of the entire power supply.

In commencing the study, it was evident that the d-c transmission losses on the UER feeder and trolley system would be the controlling economic factor in determining what kind of 60-cycle system should replace the 25-cycle system, if such replacement were thought justifiable.

MEASUREMENT OF LOSSES

THE POWER INPUT to the UER system was obtained from the 25-cycle metering at the Manchester Street Station and the 60-cycle metering at the Elmwood rectifier. By averaging the hourly requirements for the months of November and December 1946, the requirements of an average day were determined.

The net input to the d-c trolley system was obtained by subtracting from this metered input the calculated 25-cycle transmission and transformer losses and the calculated losses in conversion equipment. Values of all line and machine loadings were taken from log sheet data.

The power consumption of the trolley buses was determined from a test thus equipped with an ammeter, voltmeter, and watt-hour meter. During November and December 1946, this test bus was assigned to each scheduled route for one day, except Saturdays, Sundays, and holidays. The meters were read at each terminal of the route as well as at the dividing line between the congested downtown area and the suburban area of the city. The ammeter and voltmeter were read before and during starting. A note was made of the number of passengers, relative traffic conditions, whether the bus heaters were on or off, and the time of reading.

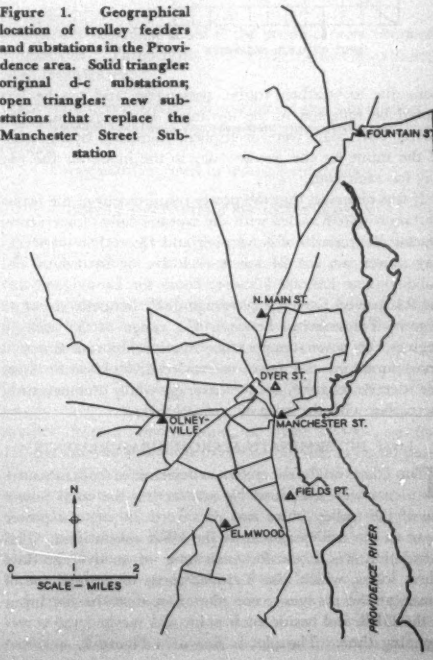

Figure 1. Geographical location of trolley feeders and substations in the Providence area. Solid triangles: original d-c substations; open triangles: new substations that replace the Manchester Street Substation

Essential text of paper 51-185, "Power Supply Study and New Rectifier Installation for the United Electric Railways of Providence," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Canada, June 25-29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The power use by all the buses on one route was determined by multiplying the test vehicle consumption for each minute of the day by the total number of vehicles scheduled on that line. A minute-by-minute summation gave the hourly power requirements of that route. A minor adjustment was introduced at this point to include the effect of a slight difference in power consumption of two different types of buses. A similar method of calculation was used for the trolley-car routes.

The test vehicle power measurements were made over a period of two months; to correct these measurements to an average day it seemed reasonable to assume that all variations due to weather, traffic, passengers, and bus heaters would be reflected in the a-c input to the system. The hourly test values were multiplied, therefore, by the ratio of the input for the average day to the input for the test day for each hour.

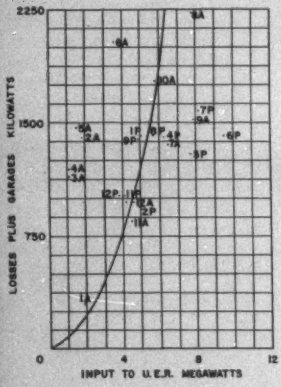

Figure 2. Trolley system losses plus garage use versus d-c input to the system

It was observed that the power requirement of the transportation system varied with the average daily temperature. During the months of November and December the weekday power use for 24 hours exclusive of Saturdays and holidays was 128,600 kilowatt hours for an average day for this period having an average daily temperature of 45 degrees Fahrenheit. Between the range of 30 and 60 degrees the power-temperature relationship was almost a linear function; the power use varied 2,000 kilowatt hours per degree change in the average daily temperature, increasing with decrease of temperature.

LOSS DETERMINATION FROM MEASUREMENTS

The losses on the d-c system as determined from measurements were obtained by subtracting the total power use of the trolley buses and cars from the net d-c power input to the trolley system at the UER substations. This calculation was made for each hour of an average day. These losses, which also included some unmetered use of power at the garages, were plotted against the d-c input to the UER and beside each point was marked the corresponding time. The plot is shown in Figure 2.

Most of the points fell reasonably close to a square-law curve, Figure 2. There were two groups that did not: (1) the values corresponding to the early morning hours between 2:00 and 6:00 a.m., and (2) the values corresponding to the rush-hour periods of 7:00 and 9:00 a.m., 5:00, 6:00, and 7:00 p.m. It was inferred that during the early morning hours most of the input was used at the garages since vehicles on the road could account for only a small part of the total use. The wide divergence of the losses at other hours of the day was the subject of prolonged study. Attempts to correlate the losses with the number of passengers carried, the bus heating use, and general traffic conditions were not conclusive.

To explain the lower losses during the rush hours, it was noted at these times the buses were concentrated in the downtown area, and because they were closer to the supply points and because of the better diversity between bus current takings, the feeder losses were not increased in proportion to the number of buses scheduled; furthermore, during the evening rush hours the average bus consumption was less, which indicated more waiting time. Losses during the morning rush hours were high compared with the afternoon rush hour periods because in the morning the buses go to the ends of the line to start their schedules, whereas in the evening the buses go downtown to start their runs.

CALCULATION OF LOSSES

The losses in the d-c feeders and trolleys caused by the bus power use were determined for the maximum number of buses that would be operating during the peak hour. On a positive feeder map of the d-c supply system the 5:30 p.m. positions of all scheduled vehicles were marked. This network was simplified to equivalent radial networks on which the identity of the bus location was retained. The maximum number of buses on any one radial feeder and trolley was 19. The loss in each section of these radial networks was determined using the rms current equivalent to the intermittent takings of the number of buses drawing power through each section of the resistance network.

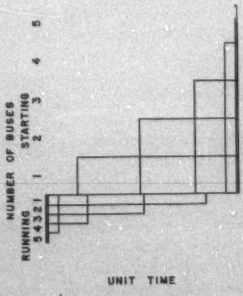

Figure 3. Relative duration and magnitude of current due to simultaneous use of starting and running power for example of ten buses. Simultaneous starting or running of six or more buses may be neglected. Unit time shown is 127 seconds

A probability method was used to determine the duration of simultaneous use of power by buses on the same feeder.

The procedure was adopted from an article by H. A. Adler and K. W. Miller.[2] The calculations were based on a cycle that was assumed to average 10 seconds' drawing starting current, 10 seconds' drawing running current, and 40 seconds of no power use in each minute.

These calculations were simplified by considering first only the starting current. The results of a calculation of probable duration of simultaneous use of starting current only for an example of 10 buses on one feeder are shown by the block steps in the upper part of Figure 3. In this case simultaneous starting of more than five buses need not be considered since simultaneous starting of six buses would be expected to occur for one second out of each 520, while that of seven buses would occur on the average of one second in each hour.

The operation of a bus on the starting, running, and stop positions are mutually exclusive events. Therefore, it was reasoned that if a bus were not taking starting current there would be a 4-to-1 chance that it would not be taking any current; hence, the probability curve of the running current requirements was assumed to be the inverse of the starting probability steps but of one-fourth the magnitude; it was fitted into the block steps of the starting current overlaps as shown by the placement in the lower part of Figure 3. The maximum number of buses taking running current would be expected to take place at a time when there would be none starting.

The rms current equivalent to the block steps of the starting and running current was calculated readily in terms of the starting current of one bus. Similar calculations were made for other numbers of buses and the results in terms of current factors k are shown in Figure 4. For any given number of buses the equivalent rms current can be obtained by reading the current factor value and multiplying by the starting current of a bus. For loss calculations a plot of k^2 was found to be convenient; when multiplied by the square of the bus starting current and the resistance of a feeder section, the power loss was obtained. The sum of the losses for positive feeder networks was doubled to include the negative feeder losses.

The first calculations were based on a bus starting current of 300 amperes as given by the maker. A comparison of the calculated peak hour feeder losses with the measured value of the peak hour losses as obtained from meter readings showed the calculated losses 45 per cent high. In practice, because of voltage drop, the starting current was observed to be between 200 and 250 amperes. The calculated losses were made equal to the measured losses by changing the assumed value of the bus starting current from 300 amperes to 229 amperes. The 24-hour losses on the average day were 18.15 times the losses on the peak hour. An annual figure was arbitrarily assumed to be 300 times the loss of the average day.

ALTERNATE METHODS OF SUPPLYING POWER

After developing a method of calculating the losses in the d-c feeder and trolley systems and correlating the calculated values with measured losses, it was possible to use this method to evaluate the relative merit of any proposed change in the power supply.

Preliminary study indicated that replacement of the present 25-cycle system of rotary converters by some type of 60-cycle rectifier installation would offer the most promise. The possibility of using comparatively small rectifiers in numerous places around the trolley system, tapped to existing 60-cycle feeders at either 4 kv or 11 kv, was studied in considerable detail. The proposed plans were examined to insure against the creation of new problems such as undesirable voltage flicker or telephone

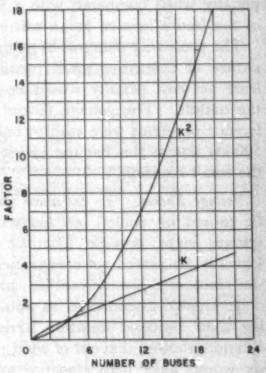

Figure 4. Current factors versus number of buses for a day of 45 degrees average temperature. To obtain the rms current equivalent for the number of buses indicated by the abscissa, multiply corresponding k value by the starting current of one bus. For loss calculations, use k^2 value and square of starting current of one bus

interference as well as to see if the proposal were economically sound. Three types of 60-cycle rectifier installations were investigated:

1. Rectifiers 500 kw and smaller on the 4-kv feeders.
2. Special locations for rectifiers tapped on the 11-kv feeders.
3. Large rectifier units in existing substations.

SMALL RECTIFIERS ON 4-KV FEEDERS

The location selected for the first study of small 60-cycle rectifiers was a high-loss radial d-c feeder that extends about 3½ miles beyond the present supply point at Olneyville and has an average of ten buses scheduled during the rush hours. The load was idealized to the extent that a uniform distance between buses was assumed. Five methods of supplying power were considered for purposes of comparison of losses; namely, a 500-kw rectifier at the supply end, a single 500-kw rectifier at the middle, or smaller units of two 300-kw, or three 200-kw, or four 150-kw units so spaced as to divide the line in equal parts. The rectifier sizes selected were standard units whose total capacity came closest to satisfying the maximum demand anticipated. In all loss calculations the probability method was used. Rectifier conversion losses were assumed to be seven per cent of the load. The results of these calculations are shown in Table I.

A comparison of these schemes shows that the greatest loss savings would be realized by using the smallest size rectifiers. However, all of these plans involve a net cost

Table I. Cost of Use of Small Rectifiers

Number of Rectifiers	Annual D-C Losses, Kilowatt Hours	Cost of Rectifier Installation	Compared with Radial Supply	
			Capitalized Loss Saving	Net Cost Penalty
Radial Supply	429,500	$ 33,000*		
1 500-kw	321,000	73,000	$ 9,500	$ 30,500
2 300-kw	219,000	108,000	18,600	56,400
3 200-kw	175,500	140,000	22,300	84,700
4 150-kw	180,000	186,000	21,900	121,000

* Based on the cost of 500 kw of capacity in a substation having 3,000 kw of rectifiers, at 1947 prices.

penalty when compared with a system at the supply end of the feeder located at an existing substation.

The preceding paragraphs pointed out the uneconomical nature of numerous small rectifiers. The one with the least net cost penalty would be the single large unit in the middle. The voltage flicker and the inductive interference problems were studied only for installations of the 500-kw size as this has the lowest net penalty attached to the small rectifiers.

Voltage Flicker. To estimate voltage flicker that would be caused by trolley bus loads on the 4-kv distribution system, eight possible locations where rectifiers might logically be placed were examined. A 2-per cent flicker was considered just noticeable; three per cent was assumed objectionable if recurrent (as would be the case); loads of less than 1-second duration were neglected. These calculations showed that out of eight possible locations studied six would have been classified as objectionable and two would have been borderline cases.

Telephone Interference. A rectifier is inherently a prolific harmonic generator. To determine the extent of the inductive interference problem with rectifiers on the 4-kv distribution system, reference was made to the AIEE Committee Report[2] describing a relatively simple analysis that makes it possible to anticipate potential inductive interference problems in rectifier installations.

The three exposures most apt to cause interference are listed as: Exposure A, to parallel communication circuits between the supply point and the rectifier, caused by harmonic currents flowing in the supply feeder; Exposure B, to communication circuits that are parallel to extensions of the line that supplies the rectifier, caused by harmonic voltages at the rectifier; Exposure C, to communication circuits that parallel other a-c feeders radiating from the same substation that supplied the rectifier and caused by harmonic voltages at the substation.

For the proposed installation of a 500-kw rectifier on the 4-kv distribution feeder 9,000 feet from the Olneyville Substation, it was determined that Exposure A between the rectifier and the supply would require further study. If the 4-kv distribution were an open-wire circuit with the neutral grounded only at the substation and if there were no unbalanced tapped loads in between, there would probably not be any interference with the communication circuits in cables; with open-wire communication circuits there might be a problem. If the 4-kv distribution circuit were multigrounded, the exposure would have been classed as very likely to cause interference with open-wire communication circuits; if paralleled by cable circuits it would have been classified as indeterminate. The Exposure B on the feeder beyond the rectifier for this proposed location would have caused trouble. The Exposure C on the feeders which are radiating from the supply station would have offered no problem.

It was concluded that this application of a 500-kw 6-phase rectifier on a 4-kv distribution feeder would cause interference on open-wire telephone lines having exposures beyond the rectifier.

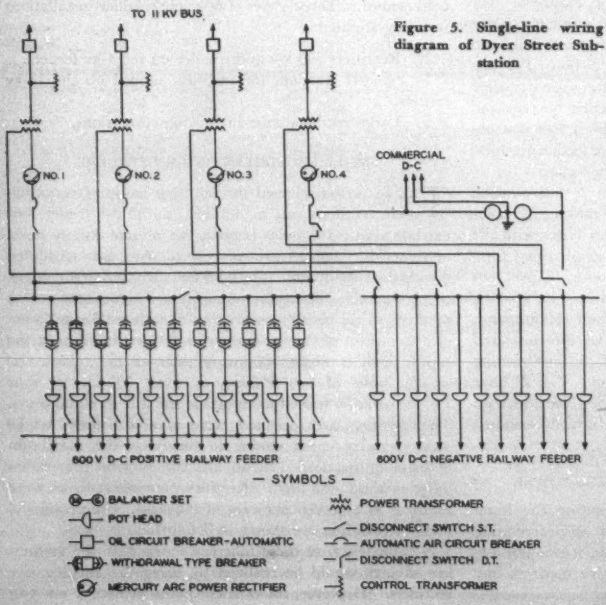

Figure 5. Single-line wiring diagram of Dyer Street Substation

SPECIAL LOCATIONS FOR RECTIFIERS ON 11-KV FEEDER

THE PRECEDING ANALYSIS showed that the application of small rectifiers on the 4-kv system was not practical. The next logical step was to examine the possibility of installing a single rectifier, tapped on an existing 11-kv industrial or tie-line feeder, in an area where comparatively large loss savings in the d-c feeders and trolley system might be realized. A 750-kw rectifier was considered at the Sprague Street Substation located about equidis-

tant from Manchester Street, Olneyville, and Elmwood.

The probability method was used to determine the number of buses that could be supplied by this station, and feeder changes were planned to take maximum advantage of the closer supply. This installation would have resulted in an annual loss saving of approximately 400,000 kilowatt hours having a capitalized value of $35,000. The extra cost of this installation over the same amount of capacity as part of a large rectifier substation was estimated to be about twice this sum.

A modified application of a rectifier supplied from an existing 11-kv 60-cycle feeder was the suggested use of a small unit to supplement the power supply to an area where the d-c feeder losses were high. It was visualized that a 300-kw rectifier could be made completely automatic and installed in a sidewalk vault. By using a reactor in the supply to obtain a drooping voltage characteristic, overloading of the small unit would be prevented.

Such an installation might be located on the so-called Prairie Avenue feeder one-half mile west of the Manchester Street Station. The calculations showed that the feeder losses would be approximately halved, thereby saving approximately 200,000 kilowatt hours of losses annually which would have a capitalized value of approximately $18,000. The estimated extra cost of such an installation over the same amount of capacity, as part of a large rectifier substation, would be approximately twice the value of losses saved.

LARGE RECTIFIERS AT PRESENT SUBSTATIONS

THE PROPOSED INSTALLATION of rectifiers on 11-kv feeders at special places, while not expected to cause problems of voltage flicker or telephone interference, would have a high net cost per kilowatt as compared with the proportionate cost of the same capacity when considered as part of a larger rectifier installation at an existing substation.

A survey of such possible locations for new rectifiers to replace the rotary converters at the Manchester Street Station showed that Dyer Street and Fields Point would be suitable. Since both are closer to the load than the Manchester Street Station, an incidental loss saving of approximately 6,000 kilowatt hours per day and a 300-kw reduction of the maximum 15-minute demand at the peak hour was expected. It was calculated that the minimum voltage at the ends of trolleys during bus starting would be improved for practically all feeders in the southeastern section of the city.

Dyer Street Substation serves the downtown area of the city and is normally operated without 600-volt d-c ties to other stations. As shown in Figure 5 there are ten railway feeders leaving the station. The positive bus to which they are connected contains a sectionalizing switch in the middle which is normally operated closed and would be opened only in case of a bus fault or for maintenance work. The feeders are arranged on the bus so that by closing outside tie switches the entire area served by the station can be carried from either half of the bus.

All equipment is fully automatic. The positive feeder circuit breakers are equipped with rate-of-rise tripping and load-measuring reclosing control. The rectifiers have load-responsive sequencing control. Voltage-controlled light-load resistors are provided to limit the voltage rise during the early morning hours when only one or two buses are on the line, and there are regenerative braking resistors to absorb any energy pumped back by dynamic braking equipment on the buses. These resistors have a combination voltage and current control.

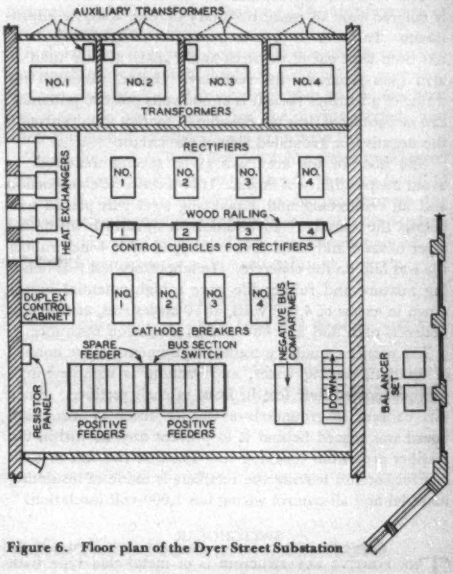

Figure 6. Floor plan of the Dyer Street Substation

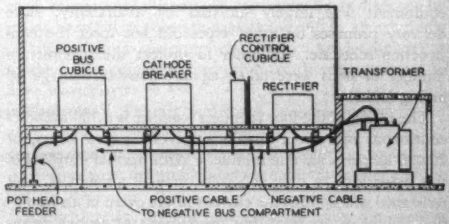

Figure 7. Typical section of the Dyer Street Substation

Figures 6 and 7 show a plan and section of the arrangement of equipment. This arrangement was designed to keep all power leads as short as possible with a minimum number of crossings. Since the building already existed, the freedom in spacing units was somewhat limited. Fortunately there was ample headroom to allow the construction of an elevated floor for all equipment except the transformers. This provided racking space for cables as

well as providing the advantage of raising the equipment above possible flood damage.

RECTIFYING EQUIPMENT

THE RECTIFIER transformers, which are double-Y with an interphase winding, are 1,000-kw 6-tank ignitron type and are cooled with water-to-air heat exchangers.

The rectifiers are located within a fenced area which is entered only to make necessary checks, tests, or adjustments. In order to protect personnel all grounded metal has been kept out of the area and a space greater than an arm span separates the rectifiers. Hence, although the frame of a rectifier (which is at 600 volts positive potential) can be contacted, it is not possible to contact simultaneously the negative or grounded side of the circuit.

The floor of the area was given special treatment to avoid the possibility of shock. It is of concrete construction and all reinforcing and supporting steel was placed well below the surface. In addition, a 3/16-inch insulating layer of sand and bond mixture topped by 1/4-inch rubber tile was laid on the concrete. In laboratory test this bonding mixture and rubber tile gave a high-potential breakdown in excess of 4,000 volts, at 60 cycles rms, at the joint between tiles, and also had a high insulation resistance.

The rectifier auxiliary control equipment for the control of ignition, cooling water, and vacuum is mounted in a cabinet located four feet in front of each rectifier. Since this cabinet is grounded, a barrier sheet of insulation board was placed behind it to prevent anyone within the rectifier area from touching it. The first two feet of each control conduit leaving the rectifiers is made of insulating material and all control wiring has 1,000-volt insulation.

SWITCHGEAR

THE POSITIVE BUS structure is of metal-clad type with drawout circuit breakers. The choice of this type of equipment was largely dictated by availability, since delivery promises on other types did not meet the construction schedule. In order to protect the structure, a number of steps were taken against possible damage by arcing faults.

The rating of the four rectifiers together is 6,700 amperes continuous operation, 10,000 amperes for two hours, or 20,000 amperes for one minute. With normal currents of this magnitude at only 600 volts, a small amount of fault resistance will so limit the current in the event of an insulation failure or arc-over that overcurrent protective relays may fail to recognize the presence of trouble. On the other hand, a sustained arc of 1,000 amperes will soon cause serious damage. With an a-c system, differential relaying could be used to provide the required sensitivity, but on a d-c system this cannot be done readily. Hence, it was decided to install the switchgear structure on insulating maple sills and ground it only through a 20-ohm resistor. The maximum fault current at the bus structure thus was reduced to 30 amperes. In the event of a fault, a voltage-measuring relay connected across the grounding resistor is arranged to trip (after a time delay) all rectifiers supplying the bus and all feeder circuit breakers. The time delay is sufficient to allow fuses on control or instrument circuits to clear any miscellaneous wiring failures.

In order to protect personnel who might be working around the bus structure at the time of a fault, the floor surrounding it was treated the same as that around the rectifiers and grounded metal was kept away from the immediate vicinity.

One of the weakest spots in the insulation of a d-c structure is the ammeters and their connections, which really form an extension of the main bus work. There have been cases on other systems where an ammeter insulation failure has started an arc which resulted in serious damage. With fault current limited to 30 amperes for a few seconds, this hazard is eliminated, but it was felt that it would be desirable, if possible, to avoid removing the entire structure from service for such minor trouble. Hence, low-resistance 5-ampere fuses were installed in all ammeter leads at the point where they leave the ammeter shunt. Although the fuses chosen were found to have quite uniform resistance, it was felt that some type of adjustment should be available to maintain instrument calibration. This was accomplished by using shunts of a higher millivolt drop than the ammeters and installing adjustable calibrating resistors. In order to avoid fuse clip resistance, fuses were obtained with bolted connections.

Another fusing problem arose in the protection of the light load and regeneration braking resistors, which together with their control devices are mounted on a wall panel. These devices require 30- and 200-ampere fuses respectively and, since connection to them comes directly from the negative and positive buses, the fuses must be able to interrupt the maximum bus fault of 75,000 amperes. Such fuses were not in production at the time but were under development; and laboratory models, which were later replaced with production units, were obtained from the manufacturer.

Each high-speed cathode circuit breaker with its bus disconnecting switch is mounted in front of the corresponding rectifier in a steel frame which sits on insulating maple sills. The frame then is grounded by a relay in parallel with a large red lamp which is mounted at the top of the frame. If the circuit-breaker insulation should fail and thus energize the frame, the relay would trip the rectifier 11-kv a-c supply and the cathode circuit breakers. If the insulation failure is on the rectifier side of the circuit breaker this operation will de-energize the frame. If the failure is on the bus side of the circuit breaker the frame will remain energized until the bus side disconnect is opened. In the meantime the red light will be lighted to warn that the frame is alive. As a further safeguard to personnel the frame and circuit breaker are totally enclosed on all sides with doors made of insulating board. In the case of Number 4 rectifier, which may be connected either to the 600-volt railway system with negative grounded or the 250/500-volt 3-wire power system with neutral grounded, the calibration of the frame ground relay and the red lamp series resistor are automatically changed, when going from one system to the other, by means of auxiliary contacts on the positive selector disconnecting switch.

The negative bus structure was designed to contain disconnect switching; at present, switches are installed

only for the four rectifiers; the outgoing feeders are tied solidly to the bus. If, in the future, the trolley system should be operated ungrounded, disconnect switches for the negative side of each feeder would also be installed. The structure frame was grounded solidly on the basis that with the negative grounded as at present, no fault can occur. If the system should be operated ungrounded, an insulation fault in this structure would be serious only if there were a simultaneous positive fault within the station. This would be a very unlikely coincidence.

Control of the rectifiers is accomplished from the master control panel which contains the instruments, control switches and relays, annunciators, and alarms for all four rectifiers. The sequence in which the rectifiers respond to load changes can be varied to equalize the hours of service between them, and, in addition, the selective equipment is arranged to pass over any units which are unavailable for service. This results in a total of some 240 operating setups which the relays must recognize. In addition, any unit may be taken out of the automatic sequence and controlled manually. The load responsive control is set to keep the equipment operating as near maximum efficiency as possible, which is between half and full load. Hence, an additional rectifier is brought into operation when the load on the machines in service reaches normal rating and a machine is dropped off when the load per machine decreases to 40 per cent. The equipment may be operated to shut down at night (after load has gone off) and start again in the morning, but since the Dyer Street area is normally isolated from the rest of the system, the control is set up to leave one unit on at all times. The annunciator system provides a record of abnormal operations that occur as well as initiating an alarm in the event that any unit is locked out.

The installation of the two 1,000-kw rectifiers at the Fields Point Substation was similar in general design features to the Dyer Street Station. The rectifiers are of the excitron type.

Both stations have now been in service a little over two years and, aside from initial shakedown troubles, operation has been satisfactory. The arc-back rate, so far, has been less than one per machine for the 2-year period, and interruptions due to other causes have been few.

When the stations were first put into service unexpected telephone interference was experienced; this was found to be due to capacitance coupling to ground through the capacitor-type lightning arresters used on the d-c feeders. The trouble was eliminated by the installation of an 0.007-inch gap in series with each lightning arrester.

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Two New Elements Confirmed by National Bureau of Standards

Recent spectroscopic investigations by the National Bureau of Standards (NBS) give positive identification of two new artificial elements. Not found in nature, the elements technetium (Tc) and promethium (Pm) are by-products of uranium fission; they were supplied by the Atomic Energy Commission. Studies at the NBS of the first optical spectra of these elements have revealed many properties of the atoms and their nuclei. They also have provided reliable wavelengths and intensity data for about 5,000 new spectral lines.

In 1949 the NBS received from the Oak Ridge National Laboratory several milligrams of each of these fission products for the purpose of making reliable descriptions and analyses of the spectra characteristic of these artifical elements. Four milligrams of highly pure Tc were used to photograph arc and spark emission spectra with a large diffraction grating. The spectra were recorded several times from 2,200 to 9,000 angstroms, and between these limits the wavelengths and relative intensities of about 2,300 radiations characteristic of Tc atoms and ions were determined. By comparing intensities in arc and spark excitation, the lines could be assigned definitely either to neutral Tc atoms or to singly ionized atoms.

Five milligrams of Pm were made available for an investigation of the absorption and emission spectra. The rare-earth character of this sample was immediately disclosed by strong bands in its absorption spectrum and by an extremely complex emission spectrum when excited by electric arcs or sparks. The principal absorption bands were observed to have wavelengths of 494.5, 548.5, 568.0, 685.5, and 735.5 millimicrons. The arc and spark emission spectra of Pm were recorded photographically with a large diffraction grating, and the wavelengths and intensities of more than 2,200 lines were determined between the ultraviolet and the red.

Unfortunately, it was not possible with the sources employed to differentiate the spectral lines of neutral and of ionized Pm atoms, and the sample was too highly radioactive to recover for further experiments in the NBS laboratory. Consequently, the preliminary description of the emission spectrum of Pm, although it confirms the discovery of the long-sought rare earth and provides a sensitive test for future identification of Pm, is at present inadequate for structural analysis and derivation of atomic energy levels.

Although several different isotopes of both elements have been made artificially, they are all radioactive. The most stable identified isotope of Tc has an atomic mass of 99 and a half-life of about 500,000 years; and for Pm the corresponding quantities are 147 and 3.7 years.

Applications of a Mechanical Differential Analyzer to Electrical Engineering

EARL JANSSEN DON LEBELL

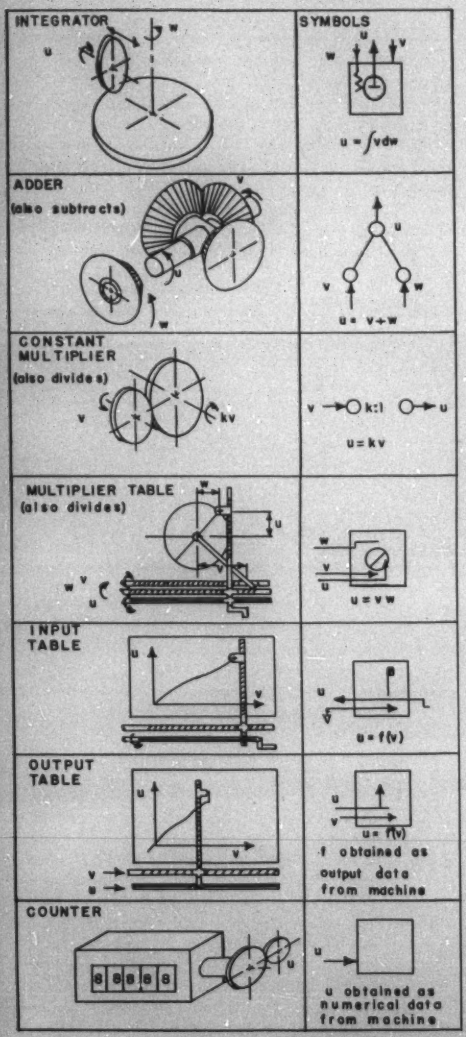

Figure 1(A). Basic components of a mechanical differential analyzer and their functions

The pertinence of the differential analyzer to the solution of certain types of electrical problems is explained by citing three examples. These examples have to do with magnetic amplifiers, pulse transformers, and particle (electron) accelerators.

THE PAST DECADE has produced an intensive and widespread series of developments in the computer field. Many dollars and man-hours have gone into computer projects with such extensive results that it has been difficult for the practicing engineer to obtain complete information on currently available computer facilities, their capabilities, and limitations. At the same time it is becoming increasingly important for the research and design engineer to have this information. He must be able to decide which computer, if any, should be employed to solve his particular problem. Too often, however, lack of information, or misinformation as to the characteristics of these devices, reduces the effectiveness of the engineer's efforts. It is the purpose of this article to point out the application to electrical engineering of one such computer, the mechanical differential analyzer. Accordingly, there follows a description of this computer and its application to the solution of representative problems in electrical engineering.

DESCRIPTION

THE OPERATING PRINCIPLES of the analyzer will be reviewed briefly since the detailed features have already been treated adequately in the literature.[1-3] The differential analyzer solves differential equations by construction within the machine of an analogue (model) of the equations to be studied. Quantities in the analogue correspond to variables in the equations to be solved; hence quantitative information about the equations can be obtained from an examination of the analogue quantities. Variables of the mechanical differential analyzer are represented by angular displacements of shafts which are interconnected to the various basic components of the machine. These basic components perform the mathematical operations indicated in Figure 1*A*. The particular selection and arrangement of components is determined by the form of the equations to be solved.

The real power of the analyzer lies in the special auxiliary operations and functions which can be produced as indicated in Figure 1*B* and the convenient means for supplying

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arbitrary functions to the analogue (Input Table, Figure 1A).

It should be kept in mind that variables in the problem correspond directly to angular positions (revolutions) of shafts. When the shaft for any given quantity is turning in a positive direction that quantity is represented as increasing, and, conversely, when the shaft is turning in a negative direction that quantity is represented as decreasing. The solution of the problem proceeds as the independent variable shaft turns. The applications to be described illustrate these features.

MAGNETIC AMPLIFIER

THE SUBJECT of magnetic amplifiers[4] is one which has recently received considerable attention. Briefly, a magnetic amplifier is a combination of specially designed reactors, generators, and rectifiers which relies on effects of reactor saturation to produce amplification of power, voltage, or current. A suitably designed reactor can be made to produce a large change in its effective impedance for a small change in the current of a d-c control (saturating) winding.

An equivalent circuit for a half-wave single-phase magnetic amplifier with self-feedback appears in Figure 2.

While it is a single-loop system whose loop voltage equation is linear, two of the circuit constants (coefficients of the differential equation) are nonlinear. The rectifier exhibits a low constant resistance to current flow in the forward direction and exhibits a high constant resistance to flow in the opposite direction. The inductance (or *B-H*) characteristic is nonlinear due to saturation effects, multiple-valued due to hysteresis effects, and further, it is affected by the d-c bias magnetomotive force and the value of total peak-to-peak steady-state core ampere turns.

These nonlinearities prohibit direct analytic solution. The usual techniques for handling nonlinear coefficients are time-consuming or produce appreciable errors in the final results. For these reasons it is highly desirable to employ the mechanical differential analyzer for solution of problems of this type.

The equation obtained from the equivalent circuit (see Figure 2) is rewritten for solution on the differential analyzer as shown in Figure 3 with the schematic setup of the analyzer for this equation. Actual solutions obtained are shown as they are plotted on the output table. Note that actual dynamic hysteresis loops characteristic of the magnetic core material to be used, and voltage-current characteristics of the rectifier obtained from test can be used directly as input data to the analyzer. Hence the usual simplifying assumptions which frequently lead to prohibitive errors are not needed to simplify or remove the nonlinearities.

PULSE TRANSFORMER

AS ANOTHER APPLICATION of the mechanical differential analyzer, consider the study of a pulse transformer.[5] Pulse trans-

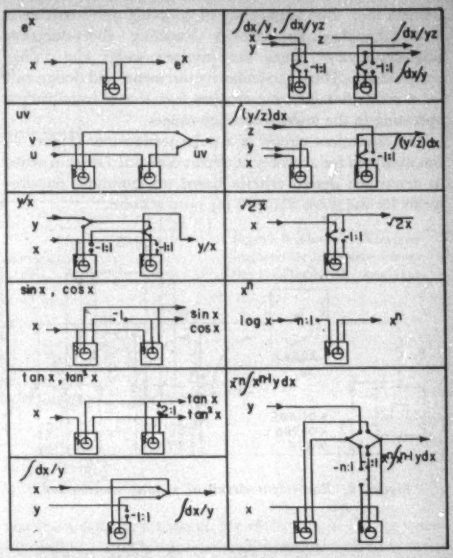


Figure 1(B). Representative auxiliary operations performed and special functions generated by a mechanical differential analyzer

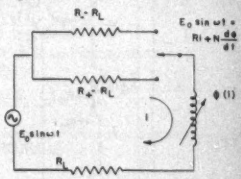
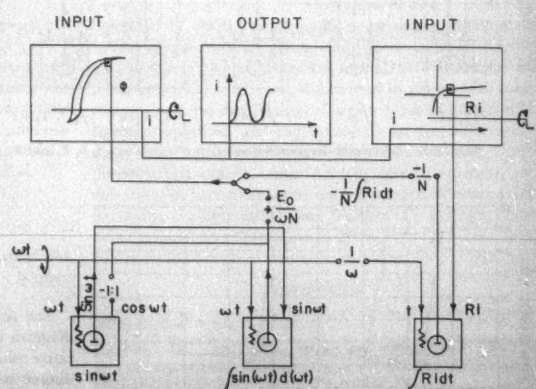


Figure 2. Equivalent circuit of a half-wave single-phase magnetic amplifier with self-feedback



$$\phi = \frac{E_0}{\omega N}\int \sin(\omega t)d(\omega t) - \frac{1}{N}\int Ri\,dt$$

Figure 3. Schematic diagram for solution of a magnetic amplifier problem

formers find wide application in coupling and impedance level changing for circuits handling short-duration (high-frequency) pulses (for instance, radar and digital computers). Their particular requirements and design call for a somewhat different analysis from that of transformers operating in the lower frequency ranges.

The equivalent circuit of a pulse transformer (Figure 4) was analyzed for a variety of circuit constant values in order to determine design criteria based on minimum requirements for the wave shape of the output pulse.

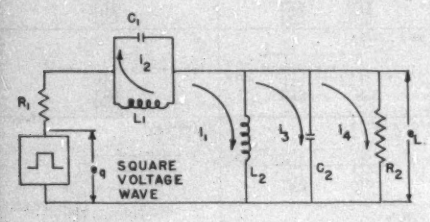


Figure 4. Equivalent circuit of a pulse transformer

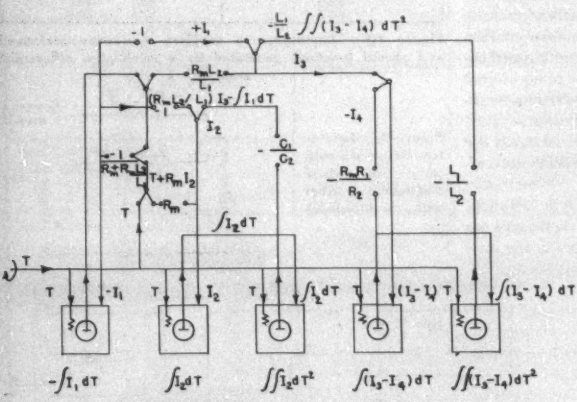


Figure 5. Schematic diagram for solution of equations 5, 6, 7, and 8

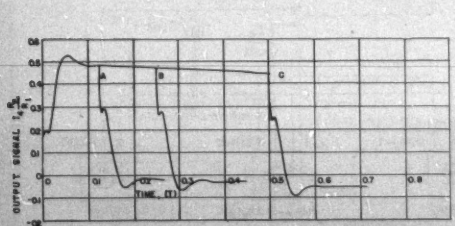


Figure 6. Representative transformer output signal wave shapes obtained from the differential analyzer. Output of pulse transformer for rectangular pulse input showing effect of varying pulse width

Simultaneous solution of the differential equations arising from the equivalent circuit can be achieved by fairly standard though tedious processes. In this particular analysis a study of the effects of changing the values of the circuit parameters was desired. This called for many solutions corresponding to several combinations of circuit constants. Therefore, although a conventional analytic solution was perfectly feasible for this problem, the differential analyzer was employed as a means of producing solutions in semi-mass-production fashion. Solution of this problem by means of an electric analogue computer would have been even more rapid. However, accuracy considerations made the mechanical differential analyzer more suitable.

The equations describing the equivalent circuit, the values of the combinations of circuit parameters, the estimated ranges of all variables, the quantities to be plotted, and the initial conditions were obtained. (This information is required before any problem can be programmed on the differential analyzer.) The loop equations obtained from the equivalent circuit (Figure 4)

$$e_q = R_1 i_1 + L_1 \frac{d}{dt}(i_1 - i_2) + L_2 \frac{d}{dt}(i_1 - i_3) \tag{1}$$

$$0 = L_1 \frac{d}{dt}(i_2 - i_1) + \frac{1}{C_1}\int i_2 dt \tag{2}$$

$$0 = L_2 \frac{d}{dt}(i_3 - i_1) + \frac{1}{C_2}\int (i_3 - i_4) dt \tag{3}$$

$$0 = \frac{1}{C_2}\int (i_4 - i_3) dt + R_2 i_4 \tag{4}$$

are rewritten in dimensionless form (for increased generality of solution).

$$1 = I_1 + R_m \frac{d}{dT}(I_1 - I_2) + R_m \frac{L_2}{L_1 dT}(I_1 - I_4) \tag{5}$$

$$0 = R_m \frac{C_2}{C_1}\int I_2 dT + R_m \frac{d}{dT}(I_2 - I_1) \tag{6}$$

$$0 = R_m \frac{L_2}{L_1}\frac{d}{dT}(I_3 - I_1) + R_m \int (I_3 - I_4) dT \tag{7}$$

$$0 = R_m \int (I_4 - I_3) dT + \frac{R_2}{R_1} I_4 \tag{8}$$

where

$$T \equiv \frac{t}{\sqrt{L_1 C_2}}$$

$$I_k \equiv i_k \frac{R_1}{e_{q(\max)}}; \quad k = 1,2,3,4$$

$$R_m \equiv \frac{1}{R_1}\sqrt{\frac{L_1}{C_2}}$$

The schematic diagram from which the final machine diagram was constructed appears in Figure 5. Representative solutions (output curves) illustrating the effects on the output pulse of certain circuit parameter variations are shown in Figure 6.

It should be noted that the equivalent circuit (Figure 4) is the result of several simplifying assumptions. The actual transformer to be simulated by the equivalent circuit could

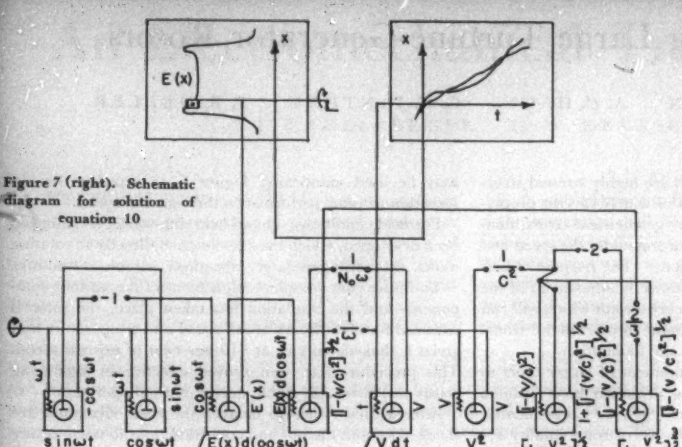


Figure 7 (right). Schematic diagram for solution of equation 10

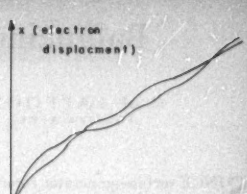


Figure 8 (above). Electron trajectories as obtained from the differential analyzer

be made to behave more nearly as the actual transformer by:

1. Considering the load resistance R_2 to vary as the actual load (perhaps a magnetron).
2. Employing the actual nonlinear characteristics of L_2 from core saturation data.
3. Increasing the number of loops, thereby simulating more nearly the distributed parameter characteristics of the actual transformer.

All these refinements could be made without adding appreciable complexity to the solution of the problem as obtained on the differential analyzer. However, these refinements would create considerable difficulty in achieving a satisfactory solution by other methods.

PARTICLE TRAJECTORIES

THE DESIGN of electron tubes, particle accelerators, and other devices utilizing the flow of particles under the influence of force fields often requires information about the trajectories of these particles. A typical example is the trajectory of a high-speed electron in a nonlinear electric field. The equation of motion in the particular direction X is

$$\mathcal{E} = \frac{d(mv)}{dt}$$

where $\mathcal{E}$ is the electric field intensity; m is the mass of the electron; v is the velocity of the electron; and t is time. The preceding equation becomes

$$\mathcal{E} = m\frac{dv}{dt}$$

except in applications where electron velocities approach the speed of light, in which case

$$\mathcal{E} = \frac{d}{dt}\left(\frac{m_0 v}{\sqrt{1-\left(\frac{v}{c}\right)^2}}\right) = m_0\left[1-\frac{v^2}{c^2}\right]^{-3/2}\frac{dv}{dt} \qquad (9)$$

where m_0 is the rest mass of the electron and c is the velocity of light. For an application of practical interest $\mathcal{E}$ varies in magnitude with distance x and sinusoidally with time; hence the relation

$$\mathcal{E} = E(x)\sin\omega t$$

where $E(x)$ is obtained from test data.

Combining this with equation 9 and integrating

$$v = \frac{1}{m_0}\int\left[1-\left(\frac{v}{c}\right)^2\right]^{3/2}E(x)\sin\omega t\,dt$$

$$= \frac{-1}{m_0\omega}\int\left[1-\left(\frac{v}{c}\right)^2\right]^{3/2}d\int E(x)d\cos\omega t \qquad (10)$$

Equation 10 is solved on the analyzer as shown in Figure 7. Solutions for various field conditions are shown in Figure 8.

The mechanical differential analyzer is capable of solving problems which can be formulated in terms of linear or nonlinear ordinary differential equations with constant or varying coefficients. Certain types of partial differential equations also can be solved on the differential analyzer by special techniques. There are now other computers which possess either greater speed, accuracy, or versatility in particular instances. However, because of its particular combination of these features it is the most suitable computer to employ for a large variety of problems and continues to be of great assistance to present-day technology.

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Balancing Large Turbine-Generator Rotors

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SINCE turbine-generator rotors are highly stressed structures that combine materials of widely varying properties, unbalance may be caused by geometrical errors, nonhomogeneity of materials, or distortion under the speed and temperature of operating conditions. The purpose of balancing is to offset these imperfections by adjustment of the rotor mass distribution so as to secure a rotor which will run so smoothly that only small periodic forces will be transmitted to the supporting bearings and foundation.

With the ever-increasing requirement of larger units to meet power demands, balancing problems have become greatly accentuated during recent years. Consequently, in order to maintain the high degree of rotor quality required for continuous reliable service without introducing serious production delays, modern practice must be able to deal effectively with all the various unbalance conditions.

Following the primary control of materials and manufacture, balancing and seasoning are performed in test rigs, Figure 1, that approximate as closely as feasible the characteristics of the assembled unit on the customer's foundation.

As part of the normal shop-balancing procedure the rotor is heated to a uniform temperature of 130 degrees centigrade in a heater box, shown in open position in Figure 1, and balanced to its normal operating speed. Since the operating speed of large rotors normally lies between the first and second critical speeds, recourse usually is made to five balance planes to obtain the best mass distribution. Vibration readings are checked at six points along the shaft.

For accurate and reliable determination of the amplitude and phase of unbalance vibration, extensive use is made of the wattmeter-type balancing equipment incorporating electromagnetic pickups and a direct-coupled sine-wave generator. The pickups, applied directly to the shaft through suitable carbon followers and lightweight pushrods, may be used seismically, Figure 1, to expedite the observation of rotor performance through test cycles.

Figure 1. Test rig for balancing large rotors

For field conditions, a hand-held sine-wave generator has been developed, which may be clutched directly to rotating shafts, to check generator vibrations without shutdown.

To insure that complete adjustment of the various components and the insulation has taken place, the rotor is seasoned for eight hours at full speed and temperature and given a shakedown run at 110 per cent of normal speed. This procedure has been proved effective in producing rotors which remain stable during normal operation.

After a final touch-up balance the rotor vibrations are checked in both the hot and cold conditions to uncover any tendency for thermal variations. With the present-day equipment and techniques, the normal balancing and seasoning period for large rotors averages approximately five days. This represents a considerable reduction from the three to five weeks once required.

Occasionally, cases are experienced where a change in balance occurs with a change in rotor temperature. Normally, these isolated cases arise from a slight bowing of the shaft such as might be produced by minor temperature variations across the diameter of the rotor or by differential expansion of the several dissimilar materials.

If the observed change is small, it is possible to make a compromise mechanical balance such that the thermal shift passes through zero while maintaining the maximum amplitudes of vibration within acceptable limits. If the change is excessive, however, it is possible to balance the rotor thermally by another method. Thermal balancing, in this case, consists essentially of neutralizing troublesome temperature distortion of the rotor by effectively introducing a counter bowing by means of an artificial temperature gradient across the diameter of the rotor. This may be accomplished simply by minor adjustments in axial ventilation using special silicone rubber plugs.

In addition to the control of unbalance vibration, procedures and techniques also must be adequate to cope with other vibration problems such as may arise from the forced vibrations of rubs and minute variations in journal contours or from the self-excited vibrations of subharmonic resonance and oil whip.

Coupling the generator rotor to the turbine rotor will alter, in general, the critical speeds of the combined unit somewhat, but the amplification factors at the operating speed will be essentially the same. Consequently, if each component is properly machined, seasoned, and balanced, the assembly also will be in balance.

Digest of paper 51-97, "Modern Practice in the Balancing of Large Turbine-Generator Rotors," recommended by the AIEE Committee on Power Generators and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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An Electromechanical Transducer

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ANY TELEMETERING SYSTEM which accomplishes the indication or recording of a physical quantity at a remote point is usually considered to consist of three major components: (1) the measuring and transducing device, (2) the transmission system, and (3) the end device.

The main transmission systems that are being used today can be divided into five general groups: the current, voltage, frequency, position, and pulse-time systems. Their names indicate the type of electric signal which is used to transmit information about the magnitude of a physical quantity from the point where it is measured to the remote station where it is converted into an indicating or recording signal. For the sake of completeness, it should be mentioned that transmission also could be in other than electrical forms, such as pneumatic or hydraulic, but these will not be considered here.

As the telemetering art progresses under the impetus of both aircraft and industrial needs, the requirement for accurate transducing becomes more and more important. This article describes a null-balance type of transducer which is inherently capable of achieving an accuracy comparable to that of present-day transmission links.

The task of the measuring and transducing device is, then, one of changing the measured variable into the particular electric signal selected for the transmission system. Except for the special cases where current or frequency themselves in the proper range are to be measured, or where the change to current or frequency could be accomplished by an electric network only, a transducing device is necessary. This includes not only the obvious cases of measuring displacements or forces but also many electrical quantities which require an intermediate transducing device to express them in terms of the electric signal chosen for transmission.

MECHANICAL DESIGN

THE ELECTROMECHANICAL transducer described here changes mechanical and certain electrical quantities into corresponding electric current, mainly for purposes of remote transmission. Operating on the principle of a continuous torque balance, the Microsen Balance actually is a small servomechanism which, because it uses an external power supply for its operation, is also capable of raising the power level of the input signal. For electrical inputs, therefore, it becomes an electromechanical amplifier whose characteristics already have been described briefly and which will be discussed here in greater detail.

Full text of paper 51-29, "An Electromechanical Transducer," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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First, with reference to Figure 1, a qualitative description of the transducer shall be presented. The Microsen Balance is a compact torque balance device which was designed to have the sensitivity of a galvanometer while being rugged enough to withstand stringent field conditions. As shown, the torque measurements are made on a balanced-beam structure wherein mechanical torques are applied through a hairspring at the fulcrum of the beam and wherein electric currents produce torque in the coil suspended in the efficient pot-type magnet. The beam floats whenever the applied torques completely balance to zero. Input to the electromechanical balance is either mechanical rotation of the hairspring or direct current running through one of the coils on the end of the beam. In any case, the beam is brought to balance by a current in the feedback coil, this current being proportional to the output electric signal. Accordingly, whenever the beam is floating, the transducer is putting out an electric signal proportional to the input signal, whether the input is electrical or mechanical.

ELECTRONIC CIRCUIT

THE ASSOCIATED electronic circuitry is relatively simple. Assuming a d-c power supply, the circuit of Figure 1 employs only one tube in a bridge circuit. Bridge unbalance is the output as well as the feedback signal.

The tube is operated as a 40-megacycle tuned-plate tuned-grid oscillator which is self-biasing. Control of the intensity of oscillation is effected by the flag on the end of the electromechanical beam structure. This flag, moving over a total distance of approximately 0.010 inch, has complete control of the oscillator output. When the flag is nearest the pancake-type grid coil, the oscillator is out of oscillation; as the flag moves away from the grid coil, oscil-

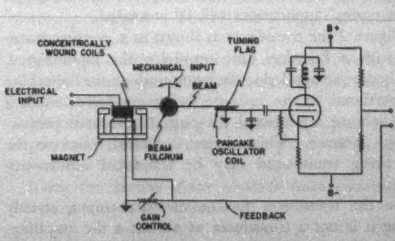

Figure 1. Schematic wiring diagram of transducer

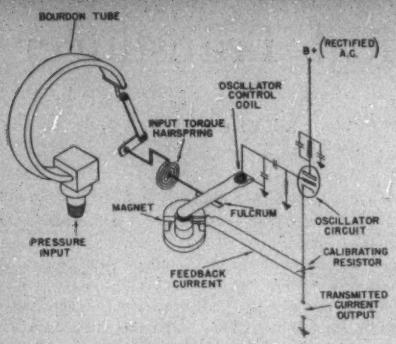

Figure 2. Transducer used as pressure transmitter

lation begins and becomes proportionally stronger. The d-c impedance of the tube in the bridge circuit varies with the intensity of oscillation, since the grid leak on the tube supplies negative bias in proportion to the oscillator output.

Thus, what is effectively being done is that the flag is varying a resistor in a bridge circuit over the range of 3,000 to 20,000 ohms with no significant force being required in the accomplishment.

It becomes evident that one possible means of transducing would be merely to have the input motion position a flag with respect to a pancake coil and then consider the bridge output as the transduced signal. The frailty of such a setup lies in the fact that other factors besides the flag motion can affect the output; such things as supply voltage and ambient temperature changes may cause appreciable shifts in the output.

This last point constitutes the main reason for including the feedback link and an electromechanical transducer which continuously measures both input and output signals and arrives at a null balance between them by controlling the output signal. This null-detection principle eliminates dependence upon variations in the electronic circuit, the accuracy of transducing being a function merely of the sensitivity of the torque-balance device.

TRANSDUCING APPLICATIONS

Before going into a more rigorous analysis of the characteristics of this transducer with regard to its servo stability criteria and ultimate accuracy, a brief description of some typical applications will be presented.

In Figure 2 the transducer is shown as a pressure transducer with a Bourdon tube supplying the input signal. Since the torque applied to the beam through the hairspring is proportional to the pressure being measured, when a torque balance is obtained the output current is proportional to pressure. This scheme is typical wherever the signal being transduced may be translated into rotary motion.

When the transducer has an electrical input, strictly speaking it is not a transducer at all but a d-c amplifier. Low-level direct currents, such as from thermocouples and strain-gauge bridges, may be amplified very accurately to a useful telemetering level. Zero drift characteristics of a wholly electronic d-c amplifier are not present since the feedback link goes back to the balance where output and input current are compared continuously in the same magnetic field.

One feature of this electromechanical d-c amplifying principle is that part of the input range may be suppressed by means of the hairspring at the beam fulcrum. For example, if the temperature band of interest for a telemetering channel were from 1,000 to 1,500 degrees Fahrenheit, the first 1,000 degrees could be suppressed, with the entire output being available for the desired temperature band. Another point, sometimes valuable, is that the input circuit is completely isolated from the rest of the amplifier.

It should be noted, however, that this unit does require current in order to develop a measurable torque; therefore, it is not useful with high-impedance-input devices such as piezoelectric crystals.

The transducer also can be used as a computer. It is possible to add and subtract both electric and mechanical signals. Because the coil in the magnetic field is wound round, as is a loudspeaker voice coil, it becomes convenient to wind a number of concentric coils on the same form and thereby allow simultaneous additive or subtractive electrical inputs which are isolated from each other. Mechanical inputs at the fulcrum obviously can also be additive or subtractive. With any combination the feedback torque balances out the net resultant torque of all the inputs, and the output is proportional to this resultant.

ACCURACY

Now an attempt shall be made to set up the fundamental relationships governing the over-all accuracy of this transducing means and to present an analysis of the unit's stability criteria and frequency-response characteristics. The symbols used in this analysis will be those established in Figure 3 and listed here.

J, gram-square centimeters, is the inertia of the beam
R, dyne-centimeters per radian per second, is velocity damping
C, dyne-centimeters per radian, is the spring rate
θ_i, radians, is the input angle to hairspring
θ_o, radians, is the deflection of beam
T_i, dyne-centimeters, is input torque to beam
T_o, dyne-centimeters, is feedback torque to beam
I_o, milliamperes, is current output of amplifier
E_o, millivolts, is voltage output of amplifier

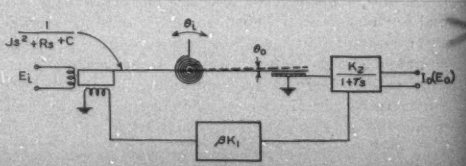

Figure 3. Operational schematic. There are three possible torque inputs: (A) direct torque application to beam, (B) direct current producing torque in coils, and (C) angular displacement of hair spring

I_i, milliamperes, is current input to amplifier
E_i, millivolts, is voltage input to amplifier
K_L, dyne-centimeters per milliampere, is feedback torque per unit of current
β is ratio of feedback to output current
$K_2(\theta) \cong K_2$ when the output current is the beam deflection
τ, seconds, is the time constant
$H(s), G(s)$ are transfer functions (see equation 1)

In considering the steady-state accuracy of the transducer, the Microsen beam is assumed to be an approximation to a null detector that compares the input with the feedback torque. Since the beam is not a perfect null detector, the current must be expressed as

$$I_o = K_1(\theta)\theta_o + K_2$$

In this expression $K_1(\theta)\theta_o$ represents the characteristic curve of output current versus beam angle, while the constant term K_2 represents extraneous shifting influences such as line-voltage variations or tube-characteristic changes. In Figure 4, an I_o verus θ_o curve is shown. As a typical example of the magnitude which may be taken by the extraneous shifting influences, curves are plotted showing the shift in the characteristic with normal line-voltage variations.

It is evident that the approximation to a null detector becomes better as the total θ_i used becomes larger with respect to the total θ_o necessary to swing through the entire output-current range. Based on the total input angle, the percentage error resulting from shifts in the output characteristic may be expressed as

$$\text{Per cent error} = 100\ \Delta\theta_o/\theta_i$$

where $\Delta\theta_o$ is the change in beam angle required to return output to the same level that existed before the shift occurred. Thus, noting in Figure 4 that the maximum shift resulting from line-voltage variation is 0.15 angular degree and assuming a total input angle of 30 degrees, the percentage error would be 0.5 per cent.

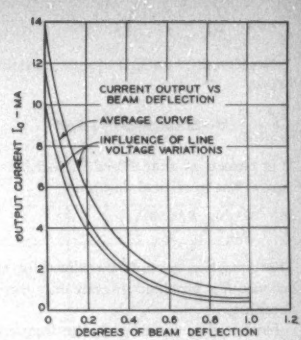

Figure 4. Characteristics of null detector

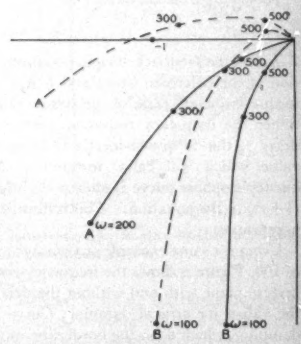

Figure 5. Stability of d-c amplifier

FREQUENCY RESPONSE

To investigate stability and frequency response, the transfer functions of the system are written as

$$\frac{I_o}{T_i - T_o} = H(s) = \frac{K_1}{(Js^2 + Rs + C)(1+\tau s)}$$

$$\frac{T_o}{I_o} = G(s) = \beta K_1 \qquad (1)$$

It should be noted that in the foregoing transfer functions K_2 has been neglected since the long time shifts are not significant in analyzing system stability. Further, for the sake of simplicity, K_2 is assumed to be a constant. This is essentially true for small deflections.

Because input is torque and output is current, $H(s)$ and $G(s)$ are not dimensionless quantities.

To investigate stability, we can write the loop transfer function as

$$H(s)G(s) = \frac{\beta K_1 K_2}{J} \frac{1}{\left(s^2 + \frac{R}{J}s + \frac{C}{J}\right)(1+\tau s)} \qquad (2)$$

Examination of equation 2 shows that without the time constant τ of the electric amplifier, the transducer would always be stable. However, due to this delay, $\beta K_1 K_2/J$ has to be limited to obtain a safe margin of stability.

As an example, the case of a voltage amplifier will be treated. The input voltage E_i is being introduced into the transducer in the form of current-producing torque (case B, Figure 3). Part of the output voltage is being fed back into another coil in the same magnetic field, producing the restoring torque.

Neglecting C, which is the torque of a small zero-adjusting spring and the current-carrying leads, we can see in Figure 5 $H(s)$ $G(s)$ both with and without the delay of the electronic amplifier. The ratio β is adjusted so as to give a voltage a gain of 100.

A delay of 0.0025 second in the oscillator circuit and amplifier will make this system unstable if the damping reduces below the critical value.

The value of the loop gain and the damping is of equal importance in determining the frequency response of the transducer.

Using the inverse plane method from equation 1 the following equations are obtained:

$$\frac{T_i}{I_o} = \frac{1}{H(s)} + G(s)$$

$$\frac{T_i}{I_o} = \beta K_1 + \frac{J}{K_2}\left(s^2 + \frac{R}{J}s + \frac{C}{J}\right)(1+\tau s) \tag{3}$$

Neglecting τs for first approximation and setting $C=0$ as before

$$\left|\frac{T_i}{I_o}\right|^2 = \frac{\omega^4}{K_2}(R^2 - 2JK_1K_2\beta + \omega^2J^2) + K_1^2\beta^2$$

R is chosen so that $R^2 - 2JK_1K_2\beta$ becomes zero, which is equivalent to critical damping.

$$\left|\frac{T_i}{I_o}\right|^2 = \frac{J^2}{K_2^2}\left(\omega^4 + \frac{K_1^2K_2^2\beta^2}{J^2}\right) \tag{4}$$

This condition cannot be realized for all values of $2JK_1K_2\beta$ because R is obtained directly only through electrodynamic damping.

Interpreting equation 4, the frequency response will be flat as long as

$$\omega^4 << \frac{K_1^2K_2^2\beta^2}{J^2} \tag{5}$$

$K_1K_2\beta$ is the feedback torque produced per radians deflection of the Microsen beam and $K_1K_2\beta/J$ can be called the torque-to-inertia ratio of the system which, in turn, determines the frequency response. However, because of the delay τ, this torque-to-inertia ratio must be kept below a value which will cause instability. Moreover, the frequency-response curve is altered slightly by the addition of $(1+\tau s)$ in the equation. This is illustrated in the following paragraphs.

Using the same example of a voltage amplifier with a gain of 100, Figure 6 shows the frequency-response curve on the inverse plane with and without the delay. Curve *B* shows the values for critical damping, Curve *A* for slight underdamping, which is on the borderline of stability, and Curve *C* for overdamping.

This frequency response is adequate for the d-c amplifier and transducer applications for which this instrument was developed. However, this analysis suggests various methods of improving this response by introducing corrective networks in either the $H(s)$ or $G(s)$ functions. In order not to impair the steady-state accuracy, only passive networks must be introduced into $G(s)$.

CURRENT TRANSMISSION SYSTEM

AT THE OUTSET it was mentioned that there are basically five established approaches to electric telemetering: the current, voltage, frequency, position, and pulse-time systems. Up to this point, the Microsen Balance has been considered only as a transducer supplying a signal at a level useful as an input to a telemetering channel. A signal of five direct volts can be converted readily into a frequency shift in a frequency-modulated channel, for example.

However, it should be recognized that this transducer also represents a transmitter for the least complicated of the five transmission techniques, the current-transmission system. In closing this discussion, the particular characteristics of d-c transmission will be considered.

Because the direct current is transmitted directly, a telemetering system of this type requires two wires between transmitter and receiver for each variable. Although several transmitters could use a common ground return, it is apparent that this system of telemetering is restricted to those applications of moderate distances where wiring does not constitute a great expenditure.

Wherever a number of signals must simultaneously be transmitted over some distance, a multichannel system becomes imperative. However, where it is applicable, current transmission offers compensation in its great simplicity, especially at the receiving end.

Next to the domestic watt-hour meter, the d'Arsonval-type d-c milliammeter is the most widely used electric instrument. It exists in a great variety of types ranging from inexpensive small meters to precision laboratory instruments. During the last few years a number of instruments with 250-degree dial arcs have contributed to increased readability and thereby greater usefulness in industrial installations. All these instruments are directly usable as receivers in this current system; it is necessary only to select a range to match that of the transducer.

For recording, any of the various self-balancing potentiometer recorders may be used with a d-c signal. This points up one significant advantage of current transmission. Standard multipoint recorders may be used for surveying a number of variables. This reduces end-device costs and permits more compact control-house layouts.

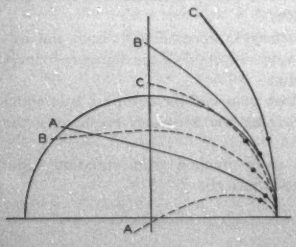

Figure 6. Frequency response of d-c amplifier

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Disturbance of Feedback Controllers

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THE FUNCTION of many industrial regulating systems is to hold some process quantity reasonably constant in the face of a diversity of disturbances which would otherwise cause that quantity to vary with time in an unacceptable manner. While such systems operate by developing corrective measures which are of opposite sign to the errors in the regulated quantity, the reference quantity, which is usually thought of as the standard of comparison, frequently does not appear explicitly.

In such a system the principal problem is that of minimizing the effects of such disturbances as changes in bus voltages, prime mover speed, and field heating. A careful analysis of such effects shows that they cannot be considered simply as additional forces imposed upon the system, but that they may appear in a number of forms. With reference to the set of equations describing the system dynamics it is found that these disturbances may:

1. Change the coefficients of one or more terms in the set of equations.
2. Add constant terms to the equations, or change the value of certain constant terms.
3. Add equations to the original set.

It is seen that these disturbances actually change the set of equations in several ways, and hence a consideration of the disturbances must be based upon both the old and the new set.

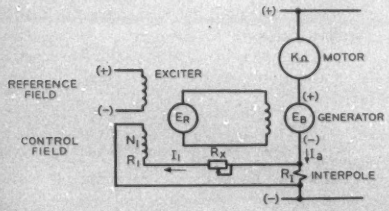

Figure 1. Current regulating system using a buck-boost generator

The current regulator shown in Figure 1 may be used as an example. The buck-boost generator serves to increase the counter electromotive force of the circuit as the current increases. If the machines operate in the saturated region of the magnetization curve, the graphical construction of Figure 2 may be used to locate the operating point. If the resistor R_x is used as a means of gain adjustment, then the characteristic in the first quadrant will change from Curve 1 to Curve 2 as the gain is increased. But this change in gain also effects the operating point unless a corresponding change is made in some other element in the system. The reference field of the exciter is used for this purpose, which is equivalent to using characteristic 3 in the first quadrant. This example serves to illustrate the fact that when a regulating system operates without an explicit standard for comparison purposes, the operating point is determined by all the elements in the circuit, and a change in any one of these elements will move the point of operation.

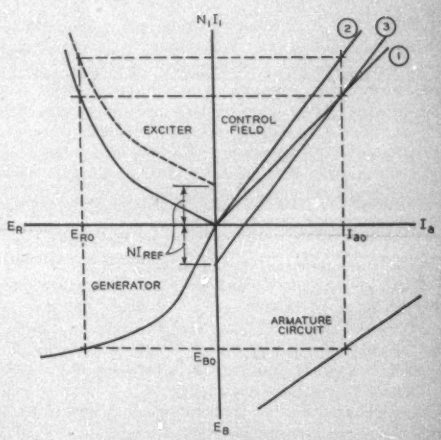

Figure 2. Graphical construction for finding equilibrium values in a nonlinear system

Disturbances or loads on the system will in some manner modify one or more of these characteristics and thus change the operating point. This matter may be studied by making another construction similar to Figure 2 using the modified characteristics. Conversely, knowing the permissible change in the operating point as a result of all disturbances, the necessary system gain can be computed from such a diagram. This is accomplished by constructing the two extreme characteristics in each quadrant whose positions will be set by the disturbances under consideration. The permissible change in operating point then determines a band which may be traced backwards through quadrants 4, 3, 2, and 1 where this bandwidth together with the permissible change in operating point will determine the necessary system gain.

Digest of paper 51-73, "The Effects of Loads and Disturbances upon Feedback Controllers," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Response of Saturable Reactor with Resistive Load

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THIS ANALYSIS deals with saturable reactors whose core material can be approximated by a rectangular magnetization curve. Such response is analyzed with respect to changes of control voltage, supply voltage, and load resistance. Operating in the proportional region, the response of the load current to any of the previous changes is an exponential function, governed by a single time constant, which varies with the load and inversely with control-circuit resistance and line frequency.

SERIES-CONNECTED SATURABLE REACTOR

DESPITE instantaneous variations of the magnetic flux in both magnetic circuits of the saturable reactor, the total flux linkage Ψ_C with the control winding is time invariant during steady-state operation. The magnitude of Ψ_C depends upon the control voltage E_C, the line voltage E, the load resistance R_L, and the supply frequency f.

If any of these parameters changes, a new level for Ψ_C will be finally established. Because Ψ_C cannot change in zero time, the new steady-state operation cannot be immediately attained and a transient results.

The transient affects Ψ_C, control and load current, and is exponential, governed by the time constant T:

$$T = \frac{1}{4f} \frac{R_L}{R_C} \frac{N_C^2}{N_L^2} \text{ seconds} \qquad (1)$$

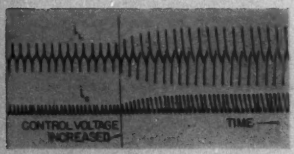

Figure 1(A). Oscillogram of load current i_L and control current i_C when control voltage is increased

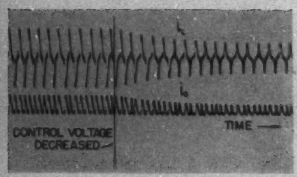

Figure 1(B). Oscillogram of load current i_L and control current i_C when control voltage is decreased

where R_C is the resistance of the control circuit, N_C is the number of turns of the control winding, and N_L is the number of turns of the load winding.

If the control voltage E_C is suddenly raised, the load current and control current will rise exponentially as shown in Figure 1*A*. Similarly, they fall exponentially when the control voltage is lowered (Figure 1*B*). By plotting the average value of load current in each half-cycle on semilog paper (Figure 2) a check is obtained with respect to the exponential character of the transient.

A sudden increase of line voltage will cause a sharp, transient increase of load current and control current which may cause damage to instruments. A sudden reduction of load

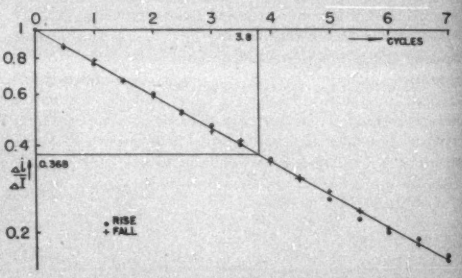

Figure 2. Relative load current changes over one-half cycle. Solid line represents calculated values, dots and crosses denote measured values

resistance will cause a transient increase in load current, thus temporarily wiping out the current-limiting character of the saturable reactor.

Defining the power gain K_p of the saturable reactor as the ratio of power output over power input, the ratio of K_p/T becomes:

$$K_p/T = 4k_f^2 \text{ per cycle} \qquad (2)$$

where k_f is the form factor of the load current and varies between 1.11 and 1.5. Equation 2 is very important, particularly in connection with servomechanism work, because the transfer function of the saturable reactor now can be written without the knowledge of any details about the saturable reactor.

PARALLEL-CONNECTED SATURABLE REACTOR

WITHOUT AN external resistance in the control winding, the time constant of the parallel-connected saturable reactor is usually twice the time constant of the series-connected reactor. If resistance is added to the control circuit of the parallel-connected saturable reactor, its time constant becomes smaller but cannot be reduced below one-half of its highest value.

Digest of paper 51-13, "Transient Response of Saturable Reactors with Resistive Load," recommended by the AIEE Committee on Industrial Control and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Power Interruption Testing of Lightning Arresters

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A LIGHTNING ARRESTER is a device which permits a practically unrestricted flow of electric current between its line and ground terminals when the terminal voltage becomes a certain multiple of its rated voltage, and which interrupts the flow of current when the overvoltage has passed. The interruption preferably should take place when the power current goes through zero for the first time after the overvoltage has disappeared. In this phase of their operating cycle lightning arresters perform as circuit breakers.

This observation applies to valve-type and expulsion-type lightning arresters alike. Their difference as interrupting devices lies in the manner in which they influence the power-follow current before current zero occurs. Valve-type lightning arresters have a nonlinear resistance characteristic chosen so that the resistance at rated voltage is very large compared to the reactance of any ordinary power source. Therefore, the power current flowing through a valve lightning arrester is practically in phase with the generated voltage. For this reason the current flow is interrupted rather easily at current zero. The interruption is accomplished by a series gap structure which consists of a number of closely spaced metal electrodes. The more the current is restricted by the valve section, the easier is the duty on the gap section as an interrupting device. Power-follow currents in valve lightning arresters are of the order of 10 to 100 amperes.

Some types of expulsion lightning arresters, particularly those for transmission-line protection, constitute the other extreme in the spectrum of interruption processes. The arc drop in such devices is so low that the power-follow current is determined almost entirely by the system itself. In most cases the system short-circuit current is preponderantly reactive; hence current zero occurs near the crest of the generated voltage. Therefore, the recovery conditions are severe. The clearing action takes place entirely in the arc channel of the expulsion device and at its electrodes; the series gap is not counted upon to contribute to the extinction process. It merely serves to insulate the expulsion device from the line while normal service voltage only is present.

In some expulsion lightning arresters for distribution service, the arc voltage developed in the deionizing channel becomes an appreciable part of the service voltage. In these cases, therefore, the expulsion lightning arrester actually limits the power-follow current, and it becomes, in this respect, more like a valve-type lightning arrester, but with one fundamental difference always remaining. In expulsion lightning arresters the series gap plays no part in the current interruption, while in valve-type lightning arresters the series or quench gap takes over at least part of the interrupting duty. That the series gap of expulsion lightning arresters cannot be expected to assist in the current interruption becomes evident if one considers the recovery characteristics of rod gaps on which very interesting information has been presented to the members of the Institnte recently.[1]

A special surge circuit has been developed for use in power interruption testing of lightning arresters. This circuit consists of a power source, a surge circuit, and an impulse timing circuit.

When testing lightning arresters for their power-current interrupting ability, the discharge usually is started by a surge generator. The surge, however, is not always followed by power current. The establishment and the severity of power current after a surge depends on the following factors:

1. Amplitude and wave shape of the surge.
2. Timing of the surge with respect to the 60-cycle voltage.
3. Voltage and current output of the power source.
4. Power factor between generated voltage and bolted fault current.
5. Circuit recovery voltage.
6. Characteristics of the interrupting device.

The importance of these features in duty-cycle testing of lightning arresters has long been realized, and they have found recognition in the various standards.[2-4] Therefore, adequate test circuits must contain means for controlling these factors.

A basic circuit which incorporates these features is shown in Figure 1. The circuit consists essentially of three sections:

1. The power source with series reactance L_1, resistance R_0, and shunt capacity C_2 to control short-circuit current and recovery voltage.
2. The surge circuit comprising surge generator, test piece, and separating gap.
3. The impulse timing circuit.

A special circuit for impulse timing has been developed

Essential text of paper 51-1, "The Power Interruption Testing of Lightning Arresters," recommended by the AIEE Committee on Protective Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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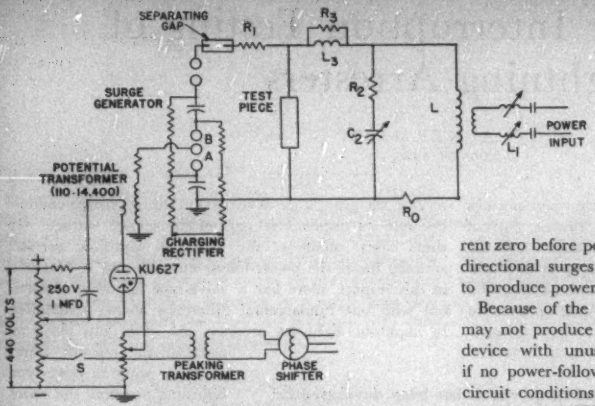

Figure 1. Basic circuit for the power interruption testing of lightning arresters

and is widely used. It is shown in the left-hand lower portion of Figure 1.

The key to the circuit is the 3-electrode gap *A-B*. When the surge generator is charged, the full voltage of the first capacitor unit appears across the gap *A* since the center electrode is grounded through an unenergized transformer. This gap is adjusted to spark over at a potential 10 to 20 per cent above the surge-generator charging voltage. The necessary increment in voltage, which must be opposite to the polarity of the charging source, is obtained by shock excitation of the potential transformer. Gap *B* must be set so that the transformer surge alone does not break it down; this should be checked with the surge generator de-energized. On the other hand, the setting of gap *B* must be smaller than that of gap *A*. With the gaps co-ordinated in this manner, *A* will spark first and *B* will follow within a fraction of a microsecond. The signal impulse in the potential transformer is produced by the discharge of a capacitor, which in turn is timed by a thyratron tube. The grid of the latter normally is kept at a direct potential so low that even the continuously superimposed voltage from the peaking transformer will not unblock it. However, if the bias level is decreased by closing the switch *S*, the first following peaking impulse of the proper polarity will open the valve. The peaking transformer is energized from a phase shifter which ties in with the power supply to the lightning arrester under test.

The surge circuit consists of the surge generator capacitors, the series resistance R_1, the test piece, and the separating gap. The function of the latter is to insulate the surge generator from the power circuit after the surge discharge. An ordinary rod gap, set as high as the surge generator voltage will permit, is sufficient in many cases. In others it is necessary to employ a regular deionizing gap. A device similar to the test piece itself often answers the purpose.

The resistor R_1, which stands for the total damping and series resistance, has the purpose of regulating intensity, duration, and wave shape of the discharge. Heavy oscillatory surges should be avoided since they may constitute an unusually favorable condition for the device to clear because of the expulsion action created by the surge or because of the introduction of a current zero before power-follow current is established. Unidirectional surges of moderate current are most likely to produce power follow.

Because of the various circuit conditions which may or may not produce power follow,[8] it is not safe to credit a device with unusually good performance characteristics if no power-follow current can be obtained, even though circuit conditions may have been varied to some extent; one can be almost certain that within the unlimited combinations of surge and power occurring in the field, power-follow current will be established under some conditions. Then the device whose design has grown around no power-follow test conditions may find itself in a situation which it is not equipped to handle. Therefore, in the testing of protective devices one should explore all reasonable means, such as controlled timing and variation of length and intensity of the surge current, to make the test piece take power follow.

In order to obtain the maximum severity discharge from a given power source, the various standards stipulate that the current flow be started as early as possible in the cycle of the generated voltage. Starting the discharge at the zero point of the generated voltage theoretically produces the longest duration of power-follow current up to the next current zero, and it also will produce the highest current peak. In practice, however, it is difficult, and in lightning arresters with very effective deionizing action even impossible, to start power follow at the zero of generated voltage. The setup which will operate most consistently usually is one in which the discharge is initiated 20 to 30 degrees after that moment.

The amplitude of the first current loop is influenced not only by the timing of the starting impulse, but also by the power factor of the circuit and by the arc voltage developed by the lightning arrester. If a current has zero per cent power factor, which implies that there be no losses at all in the circuit and hence no decrement in the d-c component, and if the discharge is started at the zero point of the generated voltage, the peak current will be twice the symmetrical crest value. This is the condition represented by the start of both curves *A* and *B* in Figure 2. If the power factor is increased while the symmetrical rms current is maintained by corresponding adjustments in the circuit reactance, the obtainable current peak decreases, as shown by curve *A*. This illustrates how the severity of tests at plants set for the same symmetrical current output can be affected by the power factor. If, on the other hand, the reactance of the power source remains fixed and the power factor is increased by adding resistance,

the obtainable peak current changes as shown by curve *B*. This curve illustrates, for instance, how drastically even moderate circuit or ground resistance reduces the service duty of an expulsion lightning arrester below what would be expected on the basis of bolted fault calculations made by considering the circuit reactance only, which is done quite frequently. It also illustrates in an approximate manner the beneficial effect of high arc drop in expulsion lightning arresters. A rigid analytical treatment of this subject was presented by Boehne a decade ago.[6]

The curves *A* and *B* in Figure 2 whose formulas are presented in AIEE *Transactions*[7] are drawn up for conditions when the power-follow current is started at the zero point of the generated voltage. As mentioned before, this is a somewhat hypothetical case because lightning arresters are likely to suppress power current under that condition. If the discharge is initiated β electrical degrees later, the crest current ratio at zero power factor, instead of being equal to 2, will be $1+\cos\beta$, which is 1.985, 1.94, and 1.87 for $\beta=10$, 20, and 30 degrees respectively. The curves *A* and *B* for the various timing angles would start, therefore, at the values quoted and would end up coinciding with the original curves at 100-per cent power factor. It is evident that the deviations from the original curves are small and that the latter can be used with little error for the purpose of this analysis. One of its objects is to show that for strictly comparative tests it is not enough to have the power sources adjusted for the same symmetrical rms current, but that the power factors also should be held within reasonably narrow limits.

Air-core reactors are the most suitable primary means for controlling the test current. They are represented by L_1 in Figure 1. The power factor is increased by inserting the resistance R_0. This resistance, as well as L_1, may be placed in either the input or the output side of the power transformer.

The recovery voltage also must be subject to control, as the natural frequency of unmodified test circuits usually is too high to be representative of the service conditions for which protective devices, particularly of the expulsion type, are designed. The frequency of the recovery voltage is controlled by the variable capacity C_2, and its amplitude by R_2[11] and by R_0. The latter affects the phase angle and thereby the instantaneous value of the generated voltage to which the circuit tries to recover.

It has long been established by studies on the recovery conditions on power systems[8-10] that the recovery voltages encountered usually are not of a single frequency. The main features of their rather variable pattern have been described by giving voltage and time for first and second crest,[8] or by the time to 90 per cent of normal, and to maximum voltage.[9] While circuits of such characteristics can readily be set up on analogue computers, it commonly is impractical to duplicate them in power laboratory tests. It is, of course, essential that the recovery conditions encountered in the field be known, but they need not be duplicated in testing. It is satisfactory if the test circuit comes reasonably close to field conditions, or better yet, if it is somewhat more severe so it will demonstrate an operating margin. It usually is not difficult to set up a circuit which, although it has only one recovery frequency, fulfills these requirements sufficiently well.[11] The time T from current zero to recovery voltage crest can be predicted with fair accuracy by considering it to be equal to one-half cycle of the natural frequency of the circuit:

$$T = 3.14\sqrt{LC_2}$$

where L is the reactance of the power supply in henrys. Expressing L in terms of the reactive short-circuit current I and of the plant voltage E, the shunt capacity required in the case of 60-cycle power becomes

$$C_2 = T^2 \times 38.2\ I/E\ 10^{-6} \text{ microfarads,}$$

where T is expressed in microseconds.

The addition of such capacity to the test circuit always poses certain difficulties. Being in parallel to the test piece it increases appreciably the demand on the surge generator output required to produce spark-over and, after spark-over, it may cause the same type of oscillatory currents as the surge generator capacitors which, as explained, may interfere with the normal functioning of the lightning arrester. Therefore, the capacitor C_2 should be separated from the test piece by a resistance R_3 or by a small reactance L_3. The resistor R_2 must be kept below certain values because of its effect on the recovery voltage.[11] In a surge circuit with negligible reactance, R_1 and R_2 determine the initial voltage available for the spark-over of the test piece. If this is insufficient, additional impedance to the drain of surge energy may be provided by the reactance L_3. It is important, however, that the C_2 L_3 circuit be kept from oscillating, particularly in tests with low power-follow currents because of the possibility of establishing unrealistic current zeros. To eliminate oscillations in the L_3 C_2 loop,

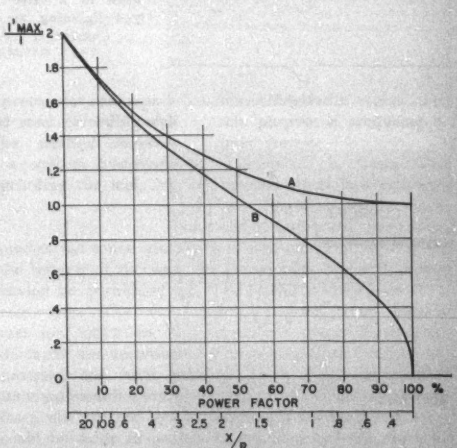

Figure 2. Ratio of maximum possible peak current to symmetrical crest current as a function of power factor. (A) Symmetrical current remaining constant; peak current equals $\sqrt{2}I_{rms}$ A; (B) Resistance being added to fixed circuit reactance X; peak current equals $(E_{rms}/X)\sqrt{2}$B

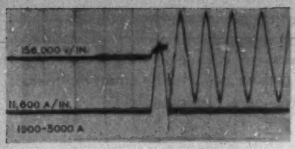

Figure 3(A). Magnetic oscillogram of a line-type expulsion lightning-arrester operation

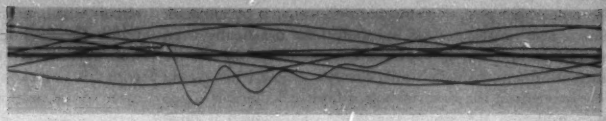

Figure 3(B). Cathode-ray oscillogram of the voltage of same line-type expulsion lightning-arrester operation as Figure 3(A)

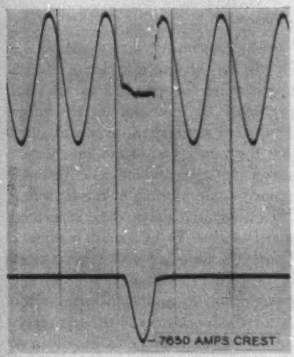

Figure 4. Operation of an expulsion lightning arrester on a 70-per cent power-factor circuit with E/X equal to 7,500 amperes rms; showing a low crest current despite maximum severity timing

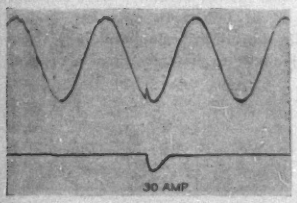

Figure 5. Power follow in a valve-type lightning arrester

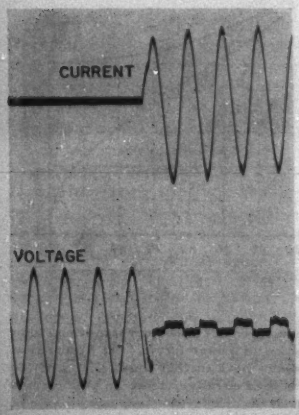

Figure 6. Failure to interrupt power follow of an experimental expulsion lightning arrester

R_3 must be about twice, or R_3 about one-half times $\sqrt{L_3/C_2}$ if either resistor is used alone.

From the foregoing discussion it is evident that before power voltage is applied, a certain amount of testing and circuit adjustment is required in order to assure that the test piece sparks over consistently. It occasionally happens that despite these preparations the lightning arrester refuses to operate when the power supply circuit is closed in. The cause for this behavior usually is found in the resultant lowering of the total circuit impedance. In this case the preliminary tests should be made with the primary of the power transformer shorted, or with the power source circuit fully connected but de-energized.

In order to evaluate tests properly, it is essential that voltages and currents be recorded adequately. The location as well as the characteristics of the measuring devices must be given proper consideration. The measurements of the recovery voltage deserve particular attention because changes in this quantity sometimes have a decisive influence on the performance of the protective device. Magnetic oscillographs, as well as potential transformers, can be relied upon for faithful recording as long as the measured frequencies are below, and not too close to, either the response limit of the vibrator element or the resonant frequency of the measuring circuit. Oscillations which can be read clearly on the magnetic record usually are far enough from these limitations and therefore are reliable. The magnetic and cathode-ray voltage records of Figures 3*A* and *B*, for instance, agree very closely, although the recorded frequency is close to 1,000 cycles. The cathode-ray oscillogram is taken over a capacity divider and is recorded on a film drum of 18-inch periphery rotating at 6,000 rpm. As the film is exposed for several revolutions of the drum the lines overlap, but the can readily be traced through.

Figure 4 shows the test of a 9-kv expulsion-type lightning arrester on a circuit whose reactance would permit a current of 7,500 amperes rms, but which had a resistance $R_0=0.83$ ohm added, making the power factor about 70 per cent. The discharge was initiated by a surge about 10 degrees from voltage zero. The current reached a crest of 7,650 amperes, which makes the crest current ratio $7{,}650/7{,}500\times1.41=0.72$. Although the effects of arc voltage are not strictly accountable, this is in good agreement with the value predicted by curve *B* in Figure 2.

Figure 5 shows the power follow in a valve-type lightning arrester. There is no voltage recovery surge because voltage and current go through zero at practically the same instant. Because of the current-limiting effect of the valve

element, the follow current is independent of the available short-circuit current.

Figure 6 is the record of the failure of an experimental expulsion lightning arrester; the sharp break in arc voltage in the first half-cycle of power follow indicates clearly that this was the crucial moment and that the integrated effects of current and arc voltage up to that point only were responsible for failure of the device.

The decisive features in performance tests, however, are not always as plainly evident as on the records cited here. Painstaking analysis of seemingly insignificant details in oscillograms, the appreciation of the functions of the various branches of test circuits, and the critical inspection of the test piece must be combined to get full value out of test efforts which are a major and quite expensive part of the engineering endeavor in the development and the application of protective devices. Their number has increased considerably in the last decade or two. With regard to their merits, staged tests cannot furnish unequivocal answers as long as the range and the effects of the many variables which influence test performance are not considered sufficiently. A broad analysis of some of these variables, in particular of impulse timing and of the power factor, has been the object of this paper.

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Recording Styli, the Burnishing Facet, and a Process for Resharpening

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A simple and inexpensive process for resharpening sapphire, stellite, and steel recording styli has been revealed. The method involves immersing the stylus in a sodium hydroxide solvent instead of regrinding the tool.

PROOF WAS established late in 1949 that dull recording styli are in most cases not dull at all. The objectionable noise produced by over 95 per cent of all damaged styli can be removed without regrinding. A unique and inexpensive device, incorporating a controlled, chemical cleaning process for resharpening all types of recording styli,[1] is now available to the recording industry.

Realizing that a process for resharpening by cleaning violates some of the long-accepted ideas about recording styli, proof of these violations will be given in this article.

THE STYLUS AND ITS BURNISHING FACET

IN ADDITION TO the ordinarily visible surfaces of the standard stylus, a tiny, flat facet is fashioned around the cutting edge of all lacquer-recording styli. This burnishing facet serves the sole purpose of producing a quiet groove.

Before F. L. Capps designed the standard lacquer-recording stylus, a stylus without a burnishing facet was used to cut sound grooves in a wax medium. Owing to the softness of the wax, the feather-edge stylus (a stylus having no burnishing facet) was able to make noise-free engravings. The wax masters produced good fidelity and low distortion, but immediate playback severely damaged the recordings. The wax masters had to be processed and hard pressings made from them. The standard recording stylus, incorporating a single burnishing facet, was designed by Mr. Capps so that sound recordings could be made in lacquer or cellulose acetate, which is sufficiently durable for immediate playback. Today virtually all phonograph records are made from lacquer originals.

Figures 1*A* and 1*B* show back and side views, respectively, of a sapphire stylus. In Figure 1*B*, it is important

Essential text of the paper awarded the Best Student Paper Prize for papers presented during the period August 1, 1949, to July 31, 1950.

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to note the exceedingly small portion of the entire sapphire that is actually used to cut the groove. A front view reveals the outline of the burnishing edge. The burnishing facet itself can be seen only in lateral aspect (Figure 1*B* inset circle) at the extreme tip of the stylus, where the width of the facet is greatest. Manufacturing methods require that the burnishing facet taper from about one mil at the tip to 0.2 mil at a point corresponding to the top of the groove wall. The burnishing facet is fashioned along

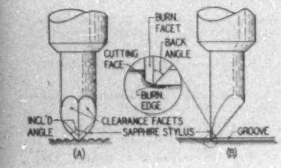

Figure 1. (A) Back and (B) side views of a sapphire stylus

the outer edge of the stylus, and no sharp point is met by the facet at the tip. Instead, the tip is circular, having a radius of about 0.2 mil.

The included angle shown in Figure 1*A* is usually 87 degrees. The importance of this angle, whether the stylus is fitted with a burnishing facet or not, is largely limited to difficulties in pressing for mass manufacture. It has been found experimentally that "horns," shown in Figure 2, become more predominant at smaller included angles.

PURPOSE OF THE BURNISHING FACET

FIGURE 3*A* shows the functional portion or cross section of the stylus in an unmodulated groove. The burnishing facet forms an angle of 25 degrees with each side wall, the leading edge of the facet cutting and the trailing edge burnishing or polishing. This polishing action leaves the groove wall smooth and free of noise.

Under modulated conditions, the stylus is carried on lateral excursions of direction and slope depending upon the magnitude and frequency of the audio signal being recorded. The angular relationship between the burnishing facet and its adjacent groove wall is then under radical change, Figure 3*B*. The 25-degree angle has been selected for optimum burnishing under most amplitude and frequency conditions. It is intended that the groove slope shall never exceed 25 degrees, at which limit the burnishng action ceases to exist, and a state of "tearing" is introduced, Figure 3*C*. This tearing of the modulated groove wall produces noise modulation, which becomes quite troublesome at high frequencies. Recently, an improved stylus having several burnishing facets has been developed which is capable of burnishing under more extreme conditions than is the ordinary standard stylus. In using this new stylus, each burnishing facet of which is considerably more narrow than the standard single facet, a better high-frequency registration was noted.

If a stylus having a small included angle is used, horns are left on the surface. The inside surface of the horns are highly polished and should not be removed. If the original is plated for purposes of pressing, it is common practice to wipe the master with a cloth, giving it a high luster. Because the horns are subjected to an uneven wiping pressure, a logical reason for this noise production might lie in the possible chipping or partial removal of these horns.

INERTIA EFFECT ON HIGH-FREQUENCY REGISTRATION

WITH A CLEAR understanding of the position and purpose of the burnishing facet in mind, some interesting derivations can be made with regard to high-frequency registration.

One theory involves the effects of high-frequency attenuation as a function of the stylus weight, the physical impedance of the recording medium in being displaced laterally, and the characteristic of the magnetic circuit delivering mechanical power to the stylus. The recording or cutting head contains the magnetic circuit to which audio-frequency power is supplied. The head transfers electric power to mechanical power. The mechanical power then is absorbed in driving the shank of the stylus laterally in accordance with the applied signal.

If the characteristic of the recording head were considered to represent the efficiency of transfer of the electric power to mechanical power over a specific range of frequencies, then the magnitude of the load absorbing this

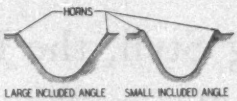

Figure 2. Larger "horns" are produced by a stylus with a small included angle

mechanical energy must be taken into consideration. Because faithful lateral motion of the stylus in engraving the grooves represents the ultimate requirement, this mechanical load may be considered as that amount of power required to overcome the impedances which act against lateral motion. Such impedances may be represented collectively as inertia.

The forces of inertia are functions of the stylus weight and the mechanical stress of the lacquer material acting against the area of the subjected portion of the burnishing facet.

High-frequency attenuation is then proportional to the forces of inertia acting against lateral movement of the stylus. Note that a decrease in the subjected area of the burnishing facet, as a result of reducing its width, will result in less structural impedance to lateral movement, less force of inertia, and ultimately, better high-frequency registration.

The reasoning to this point leads one to believe that better high-frequency registration afforded in systems of recording where smaller dimensions are used is due solely to reduced inertia.

EFFECT OF "PARALLEL DIMENSION"

THE REASONING, however, is far from adequate and conclusive. This article will introduce a new funda-

mental concept of high-frequency attenuation as a function of dimension. This concept has no bearing whatsoever on inertia, although the total force of inertia is proportional to stylus dimensions.

At this point, a definition is needed for an imaginary projection of the burnishing facet width against the groove walls.

Figure 3 shows the functional portion or cross section of the stylus. Under conditions of no modulation the burnishing facet makes an angle of 25 degrees with each groove wall. The maximum groove slope is proportional to the frequency of the audio signal.

Considering a case in which the cutting speed is 78.26 rpm and letting the frequency of the audio signal be equal to infinity, the groove slope, also, is infinity. Under such conditions, the faithful lateral movement of the stylus, in accordance with the audio signal, produces a total lateral swing which is proportional to the peak-to-peak value of the applied audio signal. The stylus has not moved, however, in the direction of cutting during the time required for the stylus to make one complete excursion or cycle laterally. Effectively, the stylus is caused to modulate a fixed point on the disc. The result is a rectangle of length (perpendicular to groove axis) proportional to the peak-to-peak value of the audio signal and width equal to the perpendicular distance from the center of the cutting face to the point of intersection of the clearance facets.

The width of the hypothetical rectangle is, however, inversely proportional to the groove depth. The degree of proportionality is a function of the back angle (an angle of approximately 45 degrees between the stylus vertical and the line of intersection of the clearance facets).

In order to justify any investigation of the effectiveness of this width in distorting the groove shape under real rather than hypothetical conditions, the least effective value of width must be used in the calculations. Because reproducing styli never track from the bottom of the groove and always ride well up on the walls, as a result of receiving lateral drive from the side walls, this width should be taken as the average projected width of the burnishing facet from

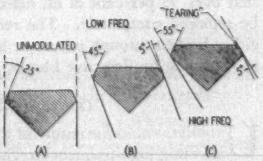

Figure 3. Relationship between burnishing angle and modulation frequency

the stylus tip to a point corresponding to the top of the groove wall. The burnishing facet width tapers from about 0.2 mil to one mil. The average width is 0.6 mil.

The projected width is defined as the quantity "parallel dimension"; this parallel dimension equals the average burnishing facet width times the cosine of the burnishing angle.

In a typical case a standard recording stylus having an average burnishing facet width of 0.6 mil is used to cut a modulated groove in a standard 10-inch disc revolving at 78.26 rpm at a radial distance of two inches in from the outside or three inches from the center. The modulation frequency is 10,000 cycles per second. Then

$$\text{Cutting speed} = \text{turntable speed} \times \text{groove circumference}$$

$$= \frac{78.26}{60} \times 6\pi = 24.55 \text{ inches per second}$$

$$\text{Recorded wave length} = \frac{\text{cutting speed}}{\text{frequency}}$$

$$= \frac{24.55}{10{,}000} = 2.455 \text{ mils}$$

$$\text{Parallel dimension} = \text{Average burnishing facet width} \times \text{cosine of burnishing angle}$$

$$= 0.6 \times \cos 25^\circ = 0.543 \text{ mil}$$

$$\text{Portion of recorded wave length occupied by parallel dimension} = \frac{\text{parallel dimension}}{\text{recorded wavelength}} = \frac{0.543}{2.455} = 22.1 \text{ per cent}$$

This means that at 10,000 cycles per second a parallel stylus dimension is occupying nearly one-fourth of the complete cycle. This causes the maximum lateral groove displacement and the point that should be on the zero axis

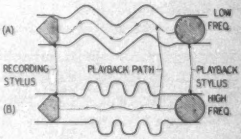

Figure 4. Effect of the facet on the groove

to coincide, thus heavily attenuating, if not completely obliterating, any registration at that frequency.

At frequencies considerably higher than 10,000 cycles per second only a wide, slopeless groove will result, permitting the playback stylus to run randomly along it. Such a groove shape is shown in Figure 4*B*. The parallel dimension of the recording stylus cuts away its own engravings after each change of direction. The playback stylus, the cross section of which is circular, is not modulated appreciably by the badly distorted groove. At a somewhat lower modulating frequency, as is shown in Figure 4*A*, registration is satisfactory. In subsequent playback, reproduction is good.

It should be noticed that this attenuating effect varies according to the radial distance of the stylus from the center of the disc.

At 33.33 rpm this reasoning is substantiated by the fact that styli intended for use at that speed must be fitted with a slightly narrower burnishing facet for good performance. Theoretically, turntable speed should have little effect on the forces of inertia, as the stress in the lacquer material is constant, regardless of speed. The development of the Anti-Noise Modulation Stylus (a stylus which has two or more very narrow burnishing facets) and the microgroove method are examples of decreases in parallel dimension, although the purpose was to decrease inertia. In addition, microgroove recordings are usually pre-emphasized

in the upper register, as in lateral transcriptions, to provide for easier equalization.

The width of the burnishing facet is, then, proportional to the attenuation of high-frequency registration for an important reason having no bearing on inertia. According to such reasoning, expensive efforts to design and build high-fidelity recording heads are useless when the stylus itself is capable of introducing such distortion. By all means, the attenuating properties of the stylus should be considered for it is not the characteristic of the magnetic circuit delivering mechanical power to the stylus that is important but, rather, the eventual recorded characteristic that is meaningful.

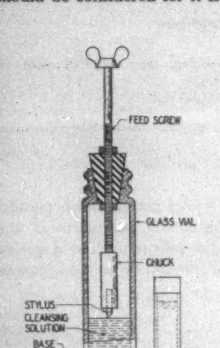

Figure 5. The complete Sapphire Tip Cleansing Instrument for use with a sodium hydroxide solvent

The high-frequency attenuation then may be considered a function of two fundamental quantities in disc recording:

1. The forces of inertia, which act against high-frequency lateral movement of the stylus while cutting.
2. The burnishing facet width, which acts as a parallel dimension, capable of serious attenuation and eventual obliteration at wavelengths sufficiently short such that the parallel dimension is appreciable with respect to the wavelength.

PROCESS AND APPARATUS

THE PRODUCTION of noise transients in disc recording is apparently associated very closely with the proper performance of the burnishing facet in polishing the groove walls. Resharpening by grinding is considered necessary when a stylus produces surface noise. This noise production is considered a result of a dull stylus.

Damages to recording styli occur frequently. Very often the stylus is caused to cut through the lacquer material and make momentary contact with the aluminum base supporting the lacquer coating. Such contact produces a highly audible hiss, and the result is a defective stylus. The hiss continues throughout the recording process and is reproduced in the form of objectionable noise during subsequent playback.

There are many causes for stylus damages. Unobserved warps or other defects in the disc contribute heavily to such troubles. Entanglement of the chip (the displaced recording material in the form of a thread) around the stylus often causes the downward pressure to be increased sufficiently so that momentary contact is made with the metal base. Care must be exercised in lowering the recording head and stylus to the revolving surface, as damages are frequently encountered in this initial operation.

An investigation was made of defective sapphire recording styli. Sapphire, Al_2O_3, is a stone having a hardness which approaches that of a diamond. It is not easily dulled or worn, particularly by aluminum, one of the softest metals. It was found that when a contact occurs between the stylus and the metal base a high surface noise is usually introduced, not because the sapphire is dulled by the aluminum but because the sapphire collects tiny pieces of aluminum. These microscopic particles usually cling to the cutting face in the vicinity of the cutting edge. Provided that the tiny particles do not extend in a lateral or downward direction far enough to produce a shadow over any part of the burnishing facet, no objectionable noise will result. In the great majority of observed cases, however, the microscopic aluminum particles extend over this critical facet, rendering it ineffective in polishing the groove wall.

A simple and unique device has been developed for cleaning sapphire, stellite, and steel styli, the trade name of which is Sapphire Tip Cleansing Instrument.[1] The apparatus is designed for use with a sodium hydroxide solvent, and the complete device is shown in Figure 5. The feed screw assembly holding the stylus chuck is lowered only until adhesion occurs between the tip and the solution. Because the chemical concentration used is only 4 per cent, little danger of exposing the metal shanks of the styli to the solvent exists, and only slight capillary action can occur in the time of five minutes required for complete resharpening.

Comprehensive tests were made to determine just how effective such a process for resharpening is. It was found that over 95 per cent of all defective styli damages could be repaired completely. The remaining 5 per cent were either broken through misuse or had been slightly chipped in recording on defective blanks.

CONCLUSIONS

UNDERSTANDING the nature of the fundamental quantities affecting high-frequency registration and reproduction might easily be the key to the development of extremely wide-band recording, such as would be needed for supersonic and possibly video recording.

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Electrical Essay

A Distortion Network

At the end of his talk on Heaviside's operators in engineering and physics in which he introduced the unit function, the time differentiator p, the "resistance operators" for the circuit constants, and the operational forms of sinusoidal functions of time, the engineer from the land of pure electrical constants invited his listeners to submit their network problems to him and he then would solve them as an illustration of his talk. One of the problems submitted from the floor may be called a distortion network and may be described as follows:

A 2-branch parallel circuit has a $C/3$ farad capacitor connected in series with an $L/3$ henry inductor in one of its branches, and an $8L/3$ henry inductor in its other branch. The network is illustrated in Figure 1. It is connected to a source of sinusoidal voltage of a frequency defined by $\omega = 1/\sqrt{LC}$. The switch connecting the network to the voltage source is accurately controlled to close and open on the crest of the voltage wave.

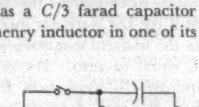

Figure 1. A distortion network

The engineer proceeds with the reduction of the network impedance to an operational form. Making $R = (8/9)(\sqrt{L/C})$ he obtains the following operational impedance:

$$Z(p) = R\frac{p(p^2+9\omega^2)}{3\omega(p^2+\omega^2)} \qquad (1)$$

Denoting by E the crest value of the voltage wave and taking into account the stipulation of controlled switching, the engineer expresses the impressed voltage as follows:

$$e = E\frac{p^2}{p^2+\omega^2}\,1 \qquad (2)$$

What currents will the network and its two branches draw when the switch is closed and when it is opened?

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Answers to Previous Essays

Ballast. The following is the author's answer to his previously published essay (*EE, Apr '51, p 351*).

The capacitor connected in parallel with the load for power-factor correction must be rated as follows:

$$Q_3 = \sin\theta\,(\text{base})\text{kva};\quad x_1 = \frac{z^2}{x}\ \text{ohm};\quad b_1 = b\ \text{mho}$$

The reactor and capacitor x_3 are resonant at the system frequency and must both be rated as follows:

$$Q_3 = \frac{\cos\theta}{\sqrt{3}}\,(\text{base})\text{kva};\quad x_2 = \sqrt{3}\,\frac{z^2}{r}\ \text{ohm};\quad b_2 = \frac{g}{\sqrt{3}}\ \text{mho}$$

Denoting by R the value of z^2/r (or $1/g$), the phase-A sequence components of line-to-neutral voltages and of line currents are related by the following:

$$E_0 = RI_0 + 2RI_1$$
$$E_1 = RI_1 + 2RI_2$$
$$E_2 = RI_2 + 2RI_0$$

The impressed values are E_1, E_2, and I_0.

E_1 = line-to-neutral voltage of line
$E_2 = 0$
$I_0 = 0$

The derived quantities then are:

$$E_0 = 2E_1$$
$$I_1 = E_1/R$$
$$I_2 = 0$$

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Seven Networks. The following is the author's answer to his previously published essay (*EE, Apr '51, pp 351–52*),

In accordance with Heaviside's rules, the inductors and capacitors are replaced with their "resistance operators" Rp/ω_0 and $R\omega_0/p$. Here $R = \sqrt{L/C}$, $\omega_0 = 1/\sqrt{LC}$, and p, the time differentiator, all follow the laws of ordinary algebra. Thus the three branches of the network of Figure 2 from left to right are expressed by the following "resistance operators:"

$$R_1 = R\frac{p^2+3\omega_0 p+\omega_0^2}{\omega_0 p+\omega_0^2}$$

$$R_2 = R\frac{p^2+3\omega_0 p+\omega_0^2}{\omega_0 p}$$

$$R_3 = R\frac{p^2+3\omega_0 p+\omega_0^2}{p^2+\omega_0 p}$$

But

$$\frac{1}{R_0} = \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

And

$$R_0 = R$$

Similarly, each network of Figure 1 reduces to the same "resistance operator" $R_0 = R$. So, all seven networks assembled by the engineer are general equivalence networks.

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Motionally Induced Electric Fields—Part VI. The following is the author's answer to his previously published essay (*EE, Apr '51, pp 350–51*).

Question 1. No, this resolving of the magnetic field

into variously moving component fields is without verifiable physical meaning and in many cases will lead to absurdities, as the next two essays will show. As was said in the preceding author's reply (*EE, Apr '51, pp 352–53*), the electric and magnetic fields in Maxwell's equations are vector fields, and nothing more; for each field, at each point of space, a direction and a magnitude, and that is all.

If in a given region we know these vector fields, we know all. We do not need to go ranging over the universe to see where our magnetic field "comes from" or "originates" to be enabled to determine what happens when a local metal body moves in a locally completely observable magnetic field.

In general, a set of differential equations like Maxwell's, including the constitutive equations, has infinitely many solutions, in spite of the fact that the number of independent equations is equal to the number of independent unknowns. To determine a solution uniquely we need what are called boundary conditions. For a local region such as that in which our metal slide bar is moving, it is enough to know the electromagnetic field vectors throughout the region at one instant of time, and to know for a sufficient time earlier, and for subsequent time, the values of the electromagnetic vectors on a closed surface enclosing the region. The fact that such boundary conditions are sufficient for fixing the solution to Maxwell's equations is the whole meaning of the statement that Maxwell theory is a "local action" theory.

Now, in our case, what happens to the metal slide bar is completely determinable from the field vectors observed over an enclosing surface surrounding the conductor and inside the iron tube. These field vectors may be determined by direct observation of the forces on momentarily stationary or moving probe charges, or we may calculate them by the method described in the author's reply to Part IV of the series (*EE, Mar '51, pp 255–56*). We find, of course, that there is a much reduced magnetic field $\mathbf{B}$, but also there is an electric field $\mathbf{E}$ observable by the force on a charged probe momentarily at rest, in the empty space inside the iron tube, and outside also, with

$$\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]=\frac{1}{c}[\mathbf{v}\times\mathbf{B}_0] \qquad (1)$$

Is this field $\mathbf{E}$ a motional field, or is it induced by varying magnetic fields? That is a meaningless question.

Now, since the constitutive equation for the metal bar inside the iron tube is

$$\mathbf{i}=\sigma\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right) \qquad (2)$$

we see by equation 1 that the flow of current in it is the same as if the bar were not inside the iron tube but was moving in the uniform magnetic field $\mathbf{B}_0$ and with the electric field $\mathbf{E}$ equal to zero. We do not need Jack's device of requiring the weak field $\mathbf{B}$ to "really" be a "stationary" field $\mathbf{B}_0$, with a nearly equal and opposite field, $\mathbf{B}-\mathbf{B}_0$, "moving" with velocity $\mathbf{v}$. There is no place in Maxwell's equations for a field velocity $\mathbf{v}$. The place for $\mathbf{v}$ is in the constitutive equations for material moving with velocity $\mathbf{v}$. Macroscopic material has the property of recognizable continuing individuality, so that for it the velocity $\mathbf{v}$ has meaning

Question 2. As the author's reply to question 1 is a bit long, the author asks the reader's indulgence in postponing the discussion of question 2 to the next issue of *Electrical Engineering*.

J. SLEPIAN (F '27)

(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Detroit Edison Puts New Steam Turbogenerator Into Operation

Southwestern Michigan's electric power supply was increased 135,000 horsepower recently with the starting up of a new steam turbogenerator at Detroit Edison's Conners Creek power plant. The 100,000-kw machine produces enough electricity to supply a city of 215,000 people. The turbogenerator cost approximately $15,000,000 and is the first of two identical units being installed at Conners Creek. The second will go into operation in September. Both were built by the Westinghouse Electric Corporation. The new generating unit weighs more than 800 tons. Steam enters the turbine at 950 degrees Fahrenheit and at a pressure of 1,300 pounds. The boilers can generate 600,000 pounds of steam per hour. The condenser requires 74,000 gallons per minute of cooling water, which is pumped directly from the Detroit River and then returned, purified, to the river. Addition of the Conners Creek generator is one step in an expansion program that will bring Detroit Edison's total power capacity to 3,000,000 horsepower by 1953.

INSTITUTE ACTIVITIES

Application of Fundamental Theory is Theme of Great Lakes District Meeting

The AIEE Great Lakes District Meeting to be held at the Hotel Loraine in Madison, Wis., May 17 through 19, 1951, has as its theme "Application of Fundamental Theory" and is designed to appeal to all electrical engineers regardless of specialization.

Every effort is being made to include Student Members of the AIEE in all activities to permit maximum contact with practicing engineers. Students may go to the regular luncheons and banquet, may take the inspection trips, and attend the sessions. Special graduate and undergraduate sessions will be held on Friday and Saturday morning. Students' wives are invited to attend all the functions arranged for the ladies.

In addition to the technical sessions, there will be luncheons, a banquet, a Student banquet, a special ladies' program, and inspection trips.

All technical sessions, including the Student sessions, will be held at the Loraine Hotel. The Student Chairmen and Faculty Counselors meeting will be held Saturday, May 19, at 9:00 a.m. in Room 2033, Electrical Engineering and Mechanics Building, University of Wisconsin. Luncheons, except the Ladies' Luncheons, will be held at the headquarters hotel (Loraine). The regular and Student banquets will be held at the Memorial Union on the University of Wisconsin campus.

ADVANCE REGISTRATION

Please register in advance by promptly filling in and mailing the advance registration card enclosed with the mailed announcement. Registration should be completed at the Registration Desk on arrival at the meeting. The Registration Desk will be open beginning the evening of May 16. A registration fee of $2 will be charged all members and $3 for all nonmembers. No fee will be required of enrolled Students or the immediate families of members.

INSPECTION TRIPS

Forest Products Laboratory. Thursday, May 17, 2:00 P. M., or Friday, May 18, 2:00 P. M. This is a United States Department of Agriculture research laboratory that directs its work toward increasing knowledge about wood and wood products. A great deal of work has been done at this laboratory on wood strengths, preservation and utilization; on paper, packaging, laminating, and wood fabrication.

Electrical Engineering and Mechanics Building. Thursday, May 17, 2:00 P. M., or Friday, May 18, 10:00 A. M. or 2:00 P. M. This is a new building which has been occupied less than one year and contains all laboratories and classrooms of the electrical engineering and mechanics departments. The laboratories, educational facilities, and materials used in construction are most modern.

Veterans Hospital. Friday, May 18, 10:00 A. M. This is a $7,000,000 nearly completed 500-bed hospital, built on a 23-acre tract overlooking Lake Mendota, containing 8 floors and penthouse. The connected electric load will be 18,000 kva and 1,200 lighting fixtures and 550,000 feet of wire will be used in the building. It contains the latest in interior wiring materials.

Utilities Tour. Inspections at convenience of those wishing to visit plants. The city of Madison is supplied with electricity and natural gas by the Madison Gas and Electric Company. Electricity is generated by a local steam plant having a capacity of 70,000 kw. The Wisconsin Power and Light Company has offices in Madison and furnishes electricity to central and southern Wisconsin. One of their newest steam plants with two 25,000-kw units installed is at Beloit. The unique feature of this plant is that the steam- and electric-generating equipment are not separated by any of the building structure.

In addition to these inspection trips, the ladies will take a tour of the University of Wisconsin and the Arboretum. There are many points of interest in Madison such as the University of Wisconsin, Capitol, machine tool industry, and scenic drives which those attending the meeting may wish to see. Members desiring to see any points of interest should inform the Registration Desk and arrangements will be made to show them whatever they wish to see.

GENERAL INFORMATION

Detailed information may be obtained at the Registration Desk, and the bulletin board

(*Continued on page 455*)

Future AIEE Meetings

North Eastern District Meeting
Hotel Syracuse, Syracuse, N. Y.
May 2–4, 1951
(*Final date for submitting papers—closed*)

AIEE Conference on Domestic Appliances
(*page 457*)
Battelle Memorial Institute, Columbus, Ohio
May 15, 1951

Great Lakes District Meeting (*page 453*)
Loraine Hotel, Madison, Wis.
May 17–19, 1951
(*Final date for submitting papers—closed*)

Summer General Meeting (*page 455*)
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(*Final date for submitting papers—closed*)

Pacific General Meeting
Multnomah Hotel, Portland, Oreg.
August 20–23, 1951
(*Final date for submitting papers—May 21*)

AIEE Conference on Aircraft Equipment
Los Angeles, Calif.
October 8–10, 1951

AIEE Conference on Fractional Horsepower and Motor Applications to Refrigeration Equipment and Pumps
Dayton, Ohio
October 11–12, 1951

Fall General Meeting
Hotel Cleveland, Cleveland, Ohio
October 22–26, 1951
(*Final date for submitting papers—June 22*)

Winter General Meeting
Hotel Statler, New York, N. Y.
January 21–25, 1952
(*Final date for submitting papers—October 23*)

Photograph courtesy of Calberne Aerial, DePere, Wis.

This is an aerial view of central Madison, where the AIEE Great Lakes District Meeting will be held May 17–19. The headquarters hotel is at the right of the photograph

Tentative Technical Program

Great Lakes District Meeting, Madison, Wis., May 17-19

Thursday, May 17

9:00 a.m. Registration

10:00 a.m. Opening Session

J. R. North, presiding

Official Welcome. Honorable Walter J. Kohler, Governor of Wisconsin

New Problems of the Institute. Titus G. LeClair, President, American Institute of Electrical Engineers

Corona Effects on Transmission Lines. C. F. Wagner, Westinghouse Electric Corporation

2:00 p.m. Generating Stations Equipments

J. P. Madgett, Jr., presiding

51-157. An Engineering Approach to Control Room Lighting. *V. L. Dzwonczyk*, American Gas and Electric Service Corporation

DP. Control System of the New 60,000 K.W. Edgewater Generating Station of the Wisconsin Power and Light Company.** *G. Schiltz*, Wisconsin Power and Light Company

DP. Unique Induction Generator Hydro Plant.** *H. H. Brown*, Wisconsin Michigan Power Company

51-158—ACO.* Squirrel Cage Induction Generator for Power Generation. *T. C. Tsao*, Consolidated Edison Company of N. Y., Inc.; *N. F. Tsang*, University of Minnesota

2:00 p.m. Induction Motors

S. Beckwith, Presiding

51-159. A Contribution to the Theory of the Deep-bar Induction Motor. *J. F. H. Douglas*, Marquette University

51-160. Split-Winding Starting of Three-Phase Motors. *P. L. Alger, H. C. Ward, Jr., F. H. Wright*, General Electric Company

DP. Performance Characteristics of the Doubly-Fed Induction Machine.** *G. W. Staats*, Allis-Chalmers Manufacturing Company

DP. Application of Thevenin's Theorem in Induction Motor Theory.** *B. S. Willis*, Iowa State College

2:00 p.m. Communication Circuits

V. C. Rideout, presiding

DP. Non-linear Element Applications to T and π Networks.** *C. J. O'Connor, G. W. Valente, H. E. Ellithorn*, University of Notre Dame

DP. Characteristics of Twin-T and Bridged-T Networks.** *J. L. Potrzebowski, M. V. Brunnagel, H. E. Ellithorn*, University of Notre Dame

DP. The Realization of a Transfer Ratio with Complex Zeros in the Form of a Three-Terminal R-C Network.** *P. F. Ordung, G. S. Axelby, H. L. Krauss, W. P. Totter*, Yale University

DP. Determination of the Resistance of a Homogeneous Screen of Linear Conductors.** *J. P. Ballantine*, University of Washington

51-161—ACO.* Hum and Stability Problems of Power Line Synchronization in Television. *W. L. Hughes*, Iowa State College

2:00 p.m. Unique Field Mapping Procedures

L. C. Larson, presiding

DP. A Direct-Current Network Analyzer for Wave-Equation and Field-Mapping Problems.** *G. W. Swenson, Jr.*, University of Wisconsin

DP. The Use of the Electrolytic Tank in Investigating Heat Flow Inside Magnet Coils.** *J. D. Horgen*, Marquette University

51-162. Mapping Techniques Applied to Fluid Mapper Patterns. *A. D. Moore*, University of Michigan

2:00 p.m. Servomechanisms

N. L. Schmitz, presiding

DP.. Multiple Mode Operation of Servomechanisms.** *D. C. McDonald*, Cook Research Laboratories

DP. Transient Response of Two-Phase Induction Motor Type Servomotor.** *K. Feng*, University of Illinois

51-163. Transient Response of Small, Two-Phase Induction Motors. *A. M. Haptin*, Northwestern University

DP. Transfer Function for a 2-Phase Induction Servo Motor.** *L. O. Brown, Jr.*, University of Illinois

Friday, May 18

8:30 a.m. Undergraduate Student Technical Papers

9:30 a.m. Transmission and Distribution

E. J. Kallevang, presiding

DP. Design Features of a New 138 Kv Transmission Line.** *F. Linder*, Dairyland Power Cooperative

DP. Analysis of Subsequent Faults.** *H. K. Anchin*, American Gas and Electric Service Corporation; *E. T. B. Gross*, Illinois Institute of Technology

DP. Symmetrical Components as Applied to Protective Relaying.** *W. K. Sonnemann*, Westinghouse Electric Corporation

DP. Low Cost Regulation of Rural Distribution Lines.** *H. C. Bern*, Allis-Chalmers Manufacturing Company

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

DP. Three-Phase Dielectric Power-Factor Measurements on Cables.** *L. W. Matsch*, Illinois Institute of Technology

51-163. Effect of the Duration of Voltage Dip on Cyclic Light Flicker. *L. Bregoff*, Consolidated Edison Company of N. Y., Inc. Presentation by title only for discussion

9:30 a.m. Industrial Electronics

R. R. Benedict, presiding

51-166. Ignitrons for Frequency-Changer Welders. *R. R. Rottler*, Westinghouse Electric Corporation

51-167. Ignitron Rectifier Power for Dynamometers. *E. L. Hulla, T. H. McCrear, J. W. Strumpfer*, Westinghouse Electric Corporation; *E. G. Morehouse*, Studebaker Corporation

51-168. A Gas Tube Inverter with the Supply Voltage Below the Breakdown Voltage. *J. M. Cage, J. C. Schuder*, Purdue University

51-169. Correlation of Temperature and Electric Fields in a Material Undergoing Dielectric Heating. *T. J. Dunsheath*, Magnaflux Corporation; *J. A. M. Lyon*, Northwestern University

9:30 a.m. Computing Devices and Techniques

J. F. Calvert, presiding

51-170. A Diode Bridge Limiter for Use with Electronic Analog Computers. *R. J. Madlaf*, Askania Regulator Company; *R. J. Parent*, University of Wisconsin

51-171—ACO.* Analog Computer Solution of a Nonlinear Differential Equation. *H. G. Markey, V. C. Rideout*, University of Wisconsin

51-172. Differential Analyzer Study of Harmonic Power Generation with Nonlinear Impedance Element. *P. E. Russell, H. A. Peterson*, University of Wisconsin

DP. An Integrally Synchronized, General Purpose Magnetic Drum Digital Computer.** *G. M. Amdahl*, University of Wisconsin

9:30 a.m. Basic Sciences

W. Richter, presiding

51-173. Dependence of Direct Sparkover Voltage of Gaps on Humidity and Time. *P. B. Jacob, Jr.*, Mississippi State College; *G. M. L. Sommerman*, Northwestern University

51-174. Calculation of the Capacitance of a Circular Annulus by the Method of Subareas. *T. J. Higgins, D. K. Reitan*, The University of Wisconsin

DP. The Magnetic Cross Valve.** *H. J. McCreary*, Automatic Electric Company

DP. Magnetic Amplifier Analysis Using Flux-Charge Theory.** *P. M. Kintner*, University of Illinois

DP. Change of Units and Conversion Formulas.** *V. P. Hessler*, University of Illinois

DP. Electric and Magnetic Units and Dimensions.** *G. R. Town*, Iowa State College

51-175. The Transient Response of Magnetic Amplifiers—Cases of Negligible Commutation. *L. A. Finzi, D. P. Chandler*, Carnegie Institute of Technology; *D. C. Beaumariage*, Bethpage, Long Island. Presentation by title only for discussion

9:30 a.m. Feedback Control Devices

L. A. Hesse, presiding

DP. Compensated Synchronous Alternator.** *H. F. Storm*, General Electric Company

DP. The Measurement and Control of Moisture in Textile Slashing.** *C. V. Bullen, R. E. Schuttz*, Barber-Colman Company

DP. Progress on a Unified Terminology for Feedback Control System.** *H. W. Cory*, Allis-Chalmers Manufacturing Company

DP. Ignorable Quantities in Feedback Controllers.** *R. W. Jones*, Northwestern University

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* ACO: Advance copies only available; not intended for publication in *Transactions*.

** DP: District paper; no advance copies are available; not intended for publication in *Transactions*.

2:00 p.m. Undergraduate Student Technical Papers

2:00 p.m. Graduate Student Technical Papers

2:00 p.m. Electrical Machinery

W. A. Lewis, presiding

51-176. Transient Analysis of Rotating Machines and Stationary Networks by Means of Rotating Reference Frames. *T. H. Ku*, Massachusetts Institute of Technology

51-177. A Design Method for Polyphase Reluctance Synchronous Motors. *C. H. Crouse*, Robbins and Myers, Inc.

DP. Effects of Unbalanced Loading in a Core Type Transformer.** *G. V. Mueller*, Purdue University

DP. Fundamentals and Applications of Eddy-Current Power Devices.** *G. H. Fredrick*, Dynamatic Corporation

DP. Self Starting, Self Compensating Synchronous Motor.** *K. L. Hansen*, Milwaukee, Wis.

51-178. Improved Core Form Transformer Winding. *E. J. Grimmer, W. L. Teague*, Westinghouse Electric Corporation. Presentation by title only for discussion

2:00 p.m. Electrical Measurements

R. E. Johnson, presiding

DP. The Three Phase Oscilloscope as an Harmonic Analyzer in Power Systems.** *E. B. Kurtz, R. H. Burkhardt*, State University of Iowa

51-179—ACO.* A Complex Wave Synthesiser. *G. Ferrara, R. L. Nadeau*, University of Detroit

51-180. Piezoelectric Crystals as Sensing Elements of Pressure, Temperature and Humidity. *E. A. Roberts, P. Goldsmith*, Armour Research Foundation

DP. A Wave Generator for the Dynamic Plot of Receiving Tube Characteristics.** *J. E. Yule*, Marquette University; *G. Koehler*, University of Wisconsin

DP. Surface Temperatures and Heat Transfer Rates of Electrically Heated Wires.** *E. A. Farber*, University of Wisconsin

2:00 p.m. Waveguides and Particle Accelerators

A. Bronwell, presiding

DP. Proton Dynamics in a Linear Accelerator.** *B. V. Hazby, H. A. Miller*, University of Minnesota

51-181—ACO.* A Variable Frequency Excitation System for a 70 MEV Synchrotron. *J. D. Ryder*, University of Illinois; *J. P. Palmer*, Oak Ridge National Laboratory

51-182. Shielded Dielectric-Rod Waveguides. *R. E. Beam, H. M. Wachowski*, Northwestern University

51-164. Dielectric Loading for Waveguide Linear Accelerators. *G. I. Cohn, G. T. Flesher*, Illinois Institute of Technology

DP. Acoustic Boundary—Layer Losses in Waveguide.** *R. F. Lambert*, University of Minnesota

2:00 p.m. Symposium on Nonlinear Electric Circuit Analysis

T. J. Higgins, presiding

DP. Almost Sinusoidal Oscillations in Systems with Several Degrees of Freedom.** *H. S. Schaffner*, University of Illinois

DP. Current Practices of Solving Nonlinear Problems Arising in Industry.** *E. J. Keller*, General Electric Company

DP. Reliable Nonlinear Networks.** *R. J. Duffin*, Carnegie Institute of Technology

DP. The Stability Theorem of Liapounoff—Its Applications.** *F. E. Bothwell*, Northwestern University

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(*Continued from page 453*)

near the desk will contain notices concerning the meeting and other events. Please consult it frequently.

SOCIAL CALENDAR

Thursday, May 17

12:00 noon Luncheon, Loraine Hotel

12:15 p.m. Ladies' Luncheon, Memorial Union

2:30 p.m. Ladies' tour of Madison, University of Wisconsin, and Arboretum

6:30 p.m. Banquet—informal. For registrants, guests, ladies, and students. Memorial Union

Friday, May 18

12:00 noon Luncheon, Loraine Hotel

1:30 p.m. Ladies' Luncheon, Style Show, and Bridge. Manchester's Madison Room

6:30 p.m. Student Banquet, Memorial Union. Address: Edwin W. Seeger, Vice-President in Charge of Development, Cutler-Hammer, Inc.

HOTEL RESERVATIONS

Members planning to attend the Great Lakes District Meeting are urged to make hotel reservations now, or as early as possible to be sure of accommodations.

Mr. E. J. Kallevang, chief engineer, Wisconsin Power and Light Company, 122 West Washington Avenue, Madison 1, Wis., asks that a copy of your request for reservations be sent to him. Please mention that you are attending the AIEE meeting when you make your reservation.

Room rate schedules for four hotels in Madison are:

Loraine Hotel (headquarters) 123 West Washington Avenue	
Single rooms	$ 4.00 to $ 6.00
Double rooms	8.00 to 10.00
Edgewater Hotel, 666 Wisconsin Avenue	
Single rooms	6.00 to 10.00
Double rooms	10.00
Twin	12.00
Park Hotel, 22 South Carroll Street	
Single rooms	3.50 to 5.00
Double rooms	5.00 to 9.00
Piper's Belmont Hotel, 31 North Pinckney Street	
Single rooms	3.50 to 5.00
Double rooms	5.00 to 8.00

Staff at work in the Electrical Standards Laboratory in the new Engineering Building at the University of Wisconsin, to be visited during the Great Lakes District Meeting

Accommodations at motor courts are available. Early reservations are necessary. Rates at motor courts are approximately $4.00 for single and $5.50 for double occupancy. Three motor courts which are close to Madison are:

Hamacher Motel (On State Trunk Highway 12, 13, and 14), 5101 University Avenue, Madison, Wis.

Mid-View Apartment Motel (State Trunk Highway 12 and 13), Middleton, Wis.

Blue Spruce Motel (On State Trunk Highway 12 and 18), 1901 East Broadway, Madison, Wis.

DISTRICT MEETING COMMITTEE

The officers of the District Meeting Committee are: Carl C. Crane, *Chairman;* Harold A. Peterson, *Vice-Chairman;* W. T. Stephens, *Secretary;* and J. R. Hafstrom, *Treasurer.*

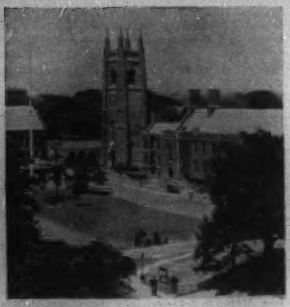
The members of the General Committee are: H. Cole, C. D. Malloch, I. B. Baccus, A. H. Lovell, C. E. Parks, D. D. Ewing, Eric T. B. Gross, J. F. Calbert, J. D. Ryder, M. S. Coover, H. S. Dixon, H. E. Hartig, J. F. H. Douglas, and W. Richter.

The Local Committee Chairmen are: *Technical Program,* T. J. Higgins; *Inspection Trips,* L. A. Hesse; *Entertainment and Sports,* G. Ansel; *Transportation,* F. D. Mackie; *Publicity,* R. E. Purucker; *Finance,* G. C. Neff; *Registration and Housing,* E. J. Kallevang; *Ladies' Activities,* Mrs. W. T. Stephens; and *Student Activities,* Dr. John Baird.

Diversified Technical Program Planned for Summer General Meeting in Toronto

A well-organized and informative technical program is being planned for the Summer General Meeting to be held from June 25 through June 29 in Toronto, Ontario, Canada. A wide variety of subjects will be covered. Among the many papers received are two from members in the United Kingdom.

At the present time Toronto is the engineering center of a major program of expansion in the generation and transmission of electric power now being carried out in the Province of Ontario. This expansion program embraces a number of new central stations, both hydro- and steam-powered.



An evening of entertainment and dancing is scheduled for those attending the Summer General Meeting in Toronto, Canada. This will be held at Hart House, the beautiful student recreational center at the University of Toronto

Because of this, much of interest will be available to visitors to this Province which has a per-capita kilowatt consumption 30 per cent greater than that of the United States of America.

ENTERTAINMENT

The Entertainment Committee reports that a reception will be held by the Lieutenant-Governor of the Province of Ontario, the Honorable Ray Lawson, and that the President's Reception, to be held Monday, June 25, at the Royal York Hotel (headquarters hotel), will take the form of a Buffet Supper and Informal Dance. A novel feature arranged by this Committee will be the Afternoon Tea to be held at the Royal York Hotel, Sunday, June 24, for the entertainment of members and guests arriving early. The program of the social evening planned at Hart House, magnificent student recreational center at the University of Toronto, will include a carillon concert from the carillon located in the Soldier's Tower, a memorial Tower to the students of the University of Toronto killed during World Wars I and II. There will be dancing in three locations, as well as a floor show and an aquatic display in the swimming pool. During the evening a visit will be made to the various parts of this beautiful building and the magnificent quadrangle which will be floodlit for the occasion.

TRAVEL ARRANGEMENTS

Arrangements have been completed with Trans Canada Airlines to allow a 10-per cent deduction for ten or more passengers originating at the same point of departure. Trans Canada Airlines also is arranging a special sight-seeing flight over Toronto and Niagara Falls. Those wishing to take advantage of this interesting feature will be able to make final arrangements on arrival at the Royal York Hotel.

Members should be sure to declare camera equipment, slides or slide films, and samples or other apparatus being brought into Canada for the purpose of demonstrations during the Meeting to the United States Customs Officials at the Border crossing point. This is important in order to facilitate the re-entry of this material into the United States.

HOTEL ACCOMMODATIONS

Rooms have been set aside at the Royal York and King Edward Hotels for the convenience of the members attending. Applications for reservations should be made directly to the hotel of choice.

Room rates for these two hotels are as follows:

Royal York Hotel (Meeting Headquarters)	Rates Per Person	
Single room	$ 6.50 to	$ 8.00
Parlour-bedroom	9.50 to	10.00
Double room	5.25 to	6.00
Parlour-bedroom	6.75 to	7.00
	Rates Per Suite	
Suites—single occupancy—bedroom and sitting-room	16.00 to	26.00
Suites—double occupancy—bedroom and sitting-room	20.00 to	31.00
King Edward Hotel		
Single room, bath (1 person)	5.00 to	6.50
Double room, double bed, bath (2 persons)	8.50 to	10.00
Double room, twin beds, bath (2 persons)	9.00 to	10.00
Two connecting rooms (3 persons)	13.50 to	16.50
Two-room suites—single occupancy	12.00 to	15.00
Two-room suites—double occupancy	15.00 to	18.00
Three-room suites—single occupancy	18.00 to	36.00
Three-room suites—double occupancy	24.00 to	36.00

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in Toronto, Ontario, Canada, at 10:00 a.m., Monday, June 25, 1951, during the Summer General Meeting.

At this meeting the annual report of the Board of Directors and the reports of the Committee of Tellers on the ballots cast for the election of officers and for the proposed amendments to the AIEE Constitution will be presented. The Lamme Medal will be presented to Donald I. Bohn (A '23, M '41, F '49).

Such other business, if any, as properly may come before the annual meeting may be considered.

Signed H. H. HENLINE
Secretary

Honor Five with Fellowship Certificates at Pittsburgh Section Annual Meeting

At its Annual Dinner Meeting on February 26, the Pittsburgh Section of AIEE bestowed the grade of Fellow on five Pittsburgh engineers. The meeting was sponsored jointly by AIEE and the Electrical Section of the Engineers' Society of Western Pennsylvania, and was held at the Schenley Hotel in Pittsburgh.

Cyril G. Veinott, Vice-President of District 2, presented Fellow certificates to: J. Stanley Brown, electrical station engineer, Duquesne Light Company; Clarence A. Atwell, design engineer, Westinghouse Electric Corporation; Royal C. Bergvall, engineering manager, Industrial Products, Westinghouse Electric Corporation; A. A. Johnson, manager, Central Station Engineering, Westinghouse Electric Corporation; and Clarence Lynn, engineering manager, Atomic Power Division, Westinghouse Electric Corporation.

The Pittsburgh Section believes that this method of presentation provides recognition which is richly deserved, and other sections may wish to follow this practice.

In presenting the Fellow Certificates, Mr. Veinott pointed out that only two per cent of the members of the Institute are eligible for the grade of Fellow, the highest grade offered. To be eligible, an engineer must have been an Associate of the Institute for six years, a Member for an additional five years, and be sponsored by five Fellows. Fellows are chosen for their training, experience, and efficiency; for notable and original work in the field of electricity; and for their ability to assume responsibility for work considered highly important by the Board of Examiners and the Board of Directors of the Institute.

Mr. Brown has had wide experience as an electrical designer and engineer for power companies throughout the country. He joined Duquesne Light Company in 1937, and was placed in charge of all electrical engineering, electrical design, and procurement of materials for power station construction. His principal work has been the design and installation of two 60,000-kw generators at the James H. Reed power station; a 65,000-kw generator for the new Frank R. Phillips station; two 80,000-kw units at the Phillips station; and two 100,000-kw units at the new Elrama station.

Mr. Atwell has been with Westinghouse Electric Corporation since 1917, when he joined the company as a tester at the East Pittsburgh works. Two years later he became a design engineer and since that time has been engaged in the development of lightweight, high-speed motors and generators for electric transportation purposes, such as mine locomotives, street cars, trolley coaches, diesel-electric buses and locomotives.

Mr. Bergvall was assigned to the general engineering department of Westinghouse at East Pittsburgh where he worked until 1934. In that year he became engineering manager for the company's Middle Atlantic District with headquarters in Philadelphia, and in 1938 he returned to Pittsburgh as assistant to the Vice-President. He assumed his present position in 1949.

Mr. Johnson co-ordinates engineering activities at Westinghouse on problems of generation, transmission, distribution, and system protection for electrical utilities and large industrial plants. He joined the company in 1941. Since then he has handled consulting engineering problems for electrical utilities and manufacturing plants.

Mr. Lynn joined Westinghouse in 1919, and a year later entered the power engineering department as a designer of d-c motors and generators. In 1928 he was made section engineer in charge of the design of d-c motors and generators. In 1941 he was awarded the Westinghouse Order of Merit

for his outstanding engineering accomplishments, and early this year was named engineering manager of the company's Atomic Power Division.

Domestic Appliances Conference to Be Held May 15 in Columbus

The Committee on Domestic and Commercial Applications is sponsoring a technical conference in Columbus, Ohio, on May 15, jointly with the Columbus Section. The main theme of the conference will be Research. The meeting will be held at Battelle Memorial Institute in Columbus, and a trip through the Institute at 2:00 p.m. is scheduled as part of the all-day program. Dr. Howard W. Russell, Assistant Director of Battelle Memorial Institute and Chief Physicist, will speak at lunch on "Research and Consumer Acceptance."

Presiding officers of the conference will be C. R. Reid, Chairman of the Subcommittee on Domestic Appliances, and C. E. Warren, Cochairman of Columbus Section and Program Chairman. C. F. Scott is Chairman of the Committee on Domestic and Commercial Applications, and Roger Merrill is Chairman of the Columbus Section, the joint sponsors of the conference.

Hotel reservations may be made at the Neil House or the Deshler-Wallach in Columbus. For further particulars and advance registration, write to Jack P. Harris, Secretary, Committee on Domestic and Commercial Applications, Cleveland Electric Illuminating Company, 75 Public Square, Cleveland 1, Ohio.

The program for the conference is as follows:

9:30 a. m.

Appliance Grounding and Its Safety Aspects. *H. B. Whitaker*, Associate Electrical Engineer, Underwriters' Laboratories

The Future of Research and Its Influence on Domestic Appliances. *A. J. Nerad*, Director of Mechanical Investigations, Research Laboratory, General Electric Company

3:30 p. m.

Some New Developments in Structural, Thermal and Electrical Insulation for Appliances. *W. Whitney Kuns*, Owens-Corning Fiberglas Company

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

General Applications Division

Committee on Production and Application of Light (*E. H. Salter, Chairman; R. C. Putnam, Vice-Chairman; R. L. Oetting, Secretary*). Plans are now under development for a session as a part of the Fall General Meeting in Cleveland on the subject of "Selection of Circuit and Lamp Design to Conserve Critical Material." This session will be cosponsored by the Committees on Distribution Systems for Industrial Plants and Distribution Systems for Commercial Buildings. It is hoped to have papers describing some new lamp and circuit developments bearing on this subject along with papers on the selection of materials from presently available sources.

Looking forward to the next Winter General Meeting, ultraviolet radiation has been selected as the topic for a session at that time. The Subcommittee on Ultraviolet Radiations will present its report.

Industry Division

Committee on Electric Heating (*J. C. Handy, Chairman; P. H. Goodell, Vice-Chairman; Harold Bunte, Secretary*). The committee held a meeting in January which was well attended and great interest was shown in the discussion. A considerable number of papers were suggested for future meetings. In order to expedite the assembling of data and information on electrical heating problems, the Chairman appointed L. P. Hynes Chairman of a new subcommittee to be known as the "Technical Data Subcommittee."

The Subcommittee on Radiation Measurements Above 300 Mc, with R. M. Baker as Chairman, has almost completed its writing of "Recommended Practice for Measurement of Field Intensities above 300 Mc from Radio Frequency Industrial, Scientific, and Medical Equipments." When this is assembled, it will be submitted to the Standards Committee of AIEE.

The Subcommittee on Induction and Dielectric Heating, W. C. Rudd, Chairman, has written and the AIEE has published the report "Good Engineering Practice in Cases of Radio Interference." The compilation of definitions is completed and is now awaiting approval of the Institute of Radio Engineers. Equipment Standards are written and are being finally assembled. There is continued review and examination of Federal Communications Commission interference reports.

The Subcommittee on Radiant Heating, with I. J. Barber as Chairman, presented an informal report of a test of infrared for veneer drying which shows considerable promise. The new infrared lamp for electric ranges may develop into a form suitable for industrial applications, so its development is being followed with interest. Also the lack of agreement as to relative merits of infrared heat sources is being studied to see if some agreement can be reached on basic principles.

Committee on Industrial Power Systems (*J. S. Gault, Chairman; H. G. Barnett, Vice-Chairman; S. A. Warner, Secretary*). A meeting of the committee held at the Winter General Meeting was attended by 21 members of the committee. Also meetings of the Executive Subcommittee and the Subcommittee on Industrial Plant Grounding were held during the Winter Meeting.

This newly organized subcommittee on Grounding, under the chairmanship of D. L. Beeman, has been especially active during the past year, and promises to present some worth-while studies in this field in the near future, starting with one or two papers at the Summer General Meeting in Toronto.

The Subcommittee on Plant Distribution Systems, H. G. Barnett, Chairman, is working on the Red Book revision, also will have some papers to present at the Summer and Fall meetings. In co-operation with the Subcommittee on Interior Wiring for Commercial Buildings, B. F. Thomas, Jr., Chairman, a session is being planned for the Fall meeting in Cleveland, sponsored jointly with the Committee on Production and Application of Light, on the subject of "Selection of Circuit and Lamp Design to Conserve Critical Material."

Power Division

Committee on Carrier Current (*S. C. Bartlett, Chairman; C. W. Boadway, Vice-Chairman (East); R. H. Miller, Vice-Chairman (West); E. W. Kenefake, Secretary*). The several subcommittees of this group are continuing work, assembling material, tabulating data, and preparing progress reports, but at the same time we see a need to reconsider the objectives. When the matter of microwave applications was first added to the scope of this Committee there was some feeling that the members were not particularly interested or qualified to handle this subject. As time passed a somewhat different view was obtained both from the interest which has been shown in the subject and practical considerations in the art of power line carrier. There is some evidence leading to the belief that power line carrier may shortly approach its peak of usefulness since many systems are fully occupying the frequency spectrum and at the same time transmission circuits are being broken down by the introduction of many more substations, making them less suitable for carrier transmission. Carrier may reasonably be expected, as time passes, to be relegated to the duties of handling short-haul work. Microwave promises to be a practical means of replacing carrier for long-haul work and it will be the problem of communications engineers to consider these, together with all other communication means within a system, to keep pace with the expansion in operating requirements, at the same time accomplishing an orderly co-ordination or transition. This group therefore feels that the present arrangement of including microwave applications within its scope is entirely proper, and with minds receptive to ideas from all sources, it may be of some value to the Institute and to the industry in general through encouraging and participating in the development of all new techniques and combinations of systems.

Science and Electronics Division

Committee on Instruments and Measurements (*W. R. Clark, Chairman; J. E. Hobson, Vice-Chairman (West); J. H. Miller, Vice-Chairman (East); J. G. Reid, Jr., Secretary; W. S. Pritchett, Secretary (West)*). Three new subcommittees have been set up within the past three months. (1) Subcommittee to Formulate a Master Test Code for Speed Measurements. The Chairman of this Subcommittee will be Mr. E. R. Thomas,

Consolidated Edison Company of New York, Inc. Its duties are to establish an AIEE Master Test Code for Measuring Speed as applied principally to Rotating Machinery. (2) Subcommittee on Recorders and Controllers. The Chairman of this Subcommittee is Mr. A. J. Hornfeck, of the Bailey Meter Company. Its function will be to sponsor papers and sessions on recording and controlling instruments, and assist in the preparation of terms used in these fields, and assist in the preparation of test codes wherever needed. (3) Subcommittee on Navigation Instruments. The Chairman of this Subcommittee will be Mr. E. J. Isbister, of the Sperry Gyroscope Company. Its function will be to sponsor papers and sessions on instruments used for all types of navigation, assist in the preparation of definitions of terms used in these fields, and assist in the preparation of test codes wherever needed. The AIEE Air Transportation Committee, the AIEE Marine Transportation Committee, and the AIEE Communication Division will all have representatives on this Subcommittee.

The Instruments and Measurements Committee has also been very active in the preparation of definitions for and specifications of various types of electronic instruments and in the formulation of an AIEE Master Test Code for Power Measurements. A report has been completed on the "Marking of Varmeters" and was presented at the Winter General Meeting. A report on the "Results of a Questionnaire Covering Current Practices in Electrical Tests on Dielectrics in the Field" has just been completed and will be presented at the forthcoming Summer General Meeting.

Committee on Therapeutics (*H. D. Moreland, Chairman; S. Reid Warren, Jr., Vice-Chairman; Scott W. Smith, Secretary*). The technical conference sponsored jointly by the Therapeutics Committee and the Electronics Subcommittee on X-Ray Tubes, Apparatus and Applications at the Winter Meeting represents a major step toward closer co-operation between the electromedical manufacturing industry and the Institute.

The combination of the Therapeutics Committee and the Subcommittee on Electrical Aids to Medicine into a single committee on "Electrical Techniques in Medicine and Biology" has been recommended by the two groups. It is believed that the union of these committees will strengthen the Institute's position not only in the electromedical branch of electrical manufacturing and application but also its co-operation with the medical profession.

AIEE PERSONALITIES . . . . .

D. C. Prince (A '16, F '26), Vice-President, General Electric Company, Schenectady, N. Y., has been named to the President's staff with special duties as assigned. Mr. Prince is a past President of the AIEE (1941–42), and Lamme Medalist (1945). He was born in Springfield, Ill., on February 5, 1891, and was graduated from the University of Illinois with a bachelor of science degree in electrical engineering in 1912, and with a master of science degree in electrical engineering in 1913. That same year he joined General Electric. A First Lieutenant in the United States Army for two years in World War I, Mr. Prince returned to General Electric and joined the research laboratory, where he conducted research on vacuum-tube applications. In 1929 he joined the Switchgear Department and shortly became chief engineer. He was appointed commercial engineer for the company in 1940, and the following year he was elected Vice-President and placed in charge of application engineering for the Apparatus Department. Mr. Prince was named head of the General Engineering Laboratory in 1945. He has been responsible for many important design developments not only in such fields as switchgear but also electric locomotives, ship control, electronic tubes, and many others. Mr. Prince has been an active member of the Institute serving as a Director (1938–44), and on the following AIEE Committees: Protective Devices; Lamme Medal; Edison Medal; Air Transportation; Technical Program; Hoover Medal Board of Award; Planning and Co-Ordination; and Executive. Mr. Prince is a member of The American Society of Mechanical Engineers and the Institute of Radio Engineers.

V. K. Zworykin (M '22, F '45), Vice-President, Technical Consultant, and Director of Electronic Research, RCA Laboratories Division, Radio Corporation of America, Princeton, N. J., has been awarded the 1951 Medal of Honor by the Institute of Radio Engineers for ". . . his outstanding contributions to the concept and development of electronic apparatus basic to modern television, and his scientific achievements that led to fundamental advances in the application of electronics to communications, to industry, and to national security." Born in Mourom, Russia, July 30, 1889, Doctor Zworykin was educated at the Petrograd Institute of Technology. Following a period of graduate work in Petrograd, during which time he performed his first experiments with television, he went to Paris in 1912 to enroll at the College of France. At the end of World War I he came to the United States, joining the research Staff of the Westinghouse Electric Corporation, East Pittsburgh, Pa. While with Westinghouse, he carried out investigations in the field of photoelectric emission. Also, he resumed his research in television, developing the basic principles of the iconoscope. In 1929, Doctor Zworykin became Director of the electronic research laboratory of the Radio Corporation of America. He was appointed to his present position in 1947. His work led to the development of such devices as secondary emission multipliers and image tubes, as well as the electron microscope. He has received two degrees since coming to the United States: doctor of philosophy, in 1926, from the University of Pittsburgh, and doctor of science, in 1938, from the Polytechnic Institute of Brooklyn. Some of the awards he has received for scientific achievements are: the Lamme Medal for 1948 from the AIEE; the Morris Liebman Memorial Prize, 1934, the Overseas Award from the British Institution of Electrical Engineers, 1939; the Rumford Medal from the American Academy of Arts and Sciences, 1941; and the Howard N. Potts Medal from the Franklin Institute, 1947. Doctor Zworykin is a member of the Institute of Radio Engineers, the American Physical Society, the American Association for the Advancement of Science, and Sigma Xi. He is the coauthor of several books on photocells, television, electron optics, and photoelectricity.

L. J. Gorman (A '11, M '30, Member for Life), assistant engineer, Electrical Engineering Department, Consolidated Edison Company, New York, N. Y., has retired after 40 years' service. He was born on April 3, 1886, at Waddington, N. Y. After graduation from Clarkson College of Technology, Mr. Gorman became associated with the

D. C. Prince

V. K. Zworykin

L. J. Gorman

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General Electric Company. In 1911, he joined the Testing Department of the New York Edison Company, to work on electrolysis surveys. Since 1921, he has had charge of all electrolysis surveys and mitigation in the company's pipe and cable systems. When the electric utilities in the New York area became consolidated as The Consolidated Edison Company of New York, his activities were augmented to meet the growing demands of the entire electrical and gas systems. His studies in the field of electrolytic corrosion of lead-covered cables and of pipe-type feeders have been recognized as pioneer achievements in this area of operations. Mr. Gorman is the author of several technical papers on the specialized theory and practice of electrolytic corrosion. He has recently become affiliated with the Robin Beach Engineers Associated, Brooklyn, N. Y., where he will act as consultant in the field of electrolytic corrosion. Mr. Gorman is one of the AIEE representatives on the Inter-society Corrosion Committee of the National Association of Corrosion Engineers. He has served in this capacity since 1948.

L. G. Pacent (M '18, F '30), President and Technical Director, Pacent Engineering Corporation, New York, N. Y., has been awarded the Marconi Memorial Medal of Achievement for his pioneer work in radio and communication. Mr. Pacent was born in New York City on June 23, 1890, and attended Pratt Institute where he studied electrical engineering with special study in electrical communication. In 1919 he founded the Pacent Electric Company for the purpose of manufacturing radio equipment and electric devices. Seven years later he founded the Pacent Corporation and in 1928 the Pacent Reproducer Corporation was begun. During the early part of his career Mr. Pacent worked very closely with Guglielmo Marconi. He has served the Institute on the Communications Committee (1939–49), and is currently serving on the AIEE Board of Examiners. Mr. Pacent is a fellow of the Institute of Radio Engineers, the Radio Club of America, and the Society of Motion Picture and Television Engineers, and a member of the Acoustical Society of America and the American Geographical Society.

M. A. Edwards (M '40, F '47), associate engineer, General Engineering and Consulting Laboratory, General Electric Company, Schenectady, N. Y., has been appointed engineering manager of the laboratory. Doctor Edwards, in his new capacity, will be responsible for all engineering activities of the laboratory and for engineering relations with other divisions and departments of the company. He was graduated from Kansas State University in 1928 and an honorary doctor of science degree was conferred on him in 1946. Doctor Edwards joined General Electric in 1929 as a student engineer. Upon completion of his first test assignment, he started work as an engineer on television and related transmission problems. In 1945 he was appointed division engineer, and in 1949 he became associate engineer in charge of the laboratory's technical divisions. Doctor Edwards holds 82 patents for ideas developed in the field of industrial controls. He is currently serving on the AIEE Research Committee. His engineering affiliations include: the Institute of Radio Engineers, Army Ordnance Association, and the American Association for the Advancement of Science.

C. Bradner Brown (A '37, M '47), chief, V-T Fuze Division, Naval Ordnance Laboratory, Washington, D. C., has been named to the position of technical assistant for the laboratory's new fuse program. Mr. Brown is a graduate of the University of Kansas, having received his bachelor of science degree in electrical engineering in 1931, and his master of science degree in 1933. He joined the Naval Ordnance Laboratory in 1941. His work there has been concerned with both magnetic- and acoustic-type mines and depth charges, as well as with various types of proximity fuses. Mr. Brown is currently serving the Institute on the Electronics and Basic Sciences Committees. He is also a member of Sigma Xi and the Society for Exploration Geophysicists.

F. K. McCune (A '33, F '49), assistant general manager, Nucleonics Department, General Electric Company, Richland, Wash., has been appointed manager of engineering of the company's large apparatus division in Schenectady, N. Y. Mr. McCune was graduated from the University of California in 1928 with a degree in electrical engineering, and that same year he joined the General Electric Company as a student engineer. He subsequently held positions in the International General Electric Company commercial department and in the General Electric West Lynn (Mass.) Works, where in 1945 he was named assistant works engineer. In 1949 he became assistant general manager of the Nucleonics Department. Mr. McCune served the Institute on the Transfers Committee (1946–48). He is also a member of Eta Kappa Nu, Sigma Xi, and Tau Beta Pi.

A. W. Edwards (A '43), design engineer, Protective Devices Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has won honorable mention in Eta Kappa Nu's outstanding young electrical engineer competition for 1950. He was born in Nashville, Tenn., on December 9, 1918, graduated from the University of Kentucky in 1937, and began work with the Westinghouse Electric Corporation after graduation in the graduate student training program. He was transferred to the Switchgear Engineering Department and his first engineering efforts were in the field of current-limiting power fuses. He has six inventions to his credit in the fuse field. During the ensuing years Mr. Edwards' field has broadened to include such devices as automatic circuit reclosers, load interrupter switches, fuse cutouts, automatic line sectionalizing devices, and other equipment associated with the distribution of electric power. This work has netted Mr. Edwards a total of 47 invention awards. He is also a member of the National Society of Professional Engineers.

W. L. Chadwick (M '38), manager, and **J. F. Davenport** (M '46), assistant Vice-President, Southern California Edison Company, Los Angeles, Calif., have been elected Vice-Presidents of the company. Mr. Chadwick was elected Vice-President in charge of engineering and construction. He joined the company in 1922, and became division engineer in 1924. From 1931 to 1937 Mr. Chadwick was senior engineer, and from 1937 he served as chief civil engineer until his appointment as manager of engineering. Mr. Davenport has been associated with the company since 1926. In 1929 he became hydro engineer, and in 1931 was appointed superintendent of hydroelectric generation for the company. He was named superintendent of generation in 1937, and assistant manager of operation in 1940. He was elected assistant Vice-President in 1946.

D. R. Yennie (A '47), graduate student in physics, Columbia University, New York, N.Y., is one of the scientists who has been named by the Bell Telephone Laboratories to receive one of the 1951–52 Frank B. Jewett postdoctoral fellowships. The awards, designed to stimulate and further the work of researchers in the physical sciences, grant $3,000 to the recipient and $1,500 to the institution at which he chooses to do his research. Mr. Yennie will receive his doctor's degree in physics this year from Columbia University, where he is studying on an Atomic Energy Commission fellowship. He received a master of engineering degree from Stevens Institute of Technology, Hoboken, N.J., in 1945, and was a physics instructor there in 1946–47. His research, dealing with the theory of elementary particles, will be conducted at the Institute for Advanced Study.

R. S. Kersh (A '42, M '45), manager, Central Station Sales Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named manager of the steam division, South Philadelphia, Pa. Mr. Kersh was graduated from Mississippi State College in 1929 with a bachelor of science degree in electrical engineering. He joined Westinghouse that same year and was assigned to the Industrial Sales Department. From 1931 to 1938 he was occupied with sales work in the Atlanta, Ga., and Birmingham, Ala., offices of the company, after which he returned to the East Pittsburgh plant as a member of the machinery electrification department. In 1942, Mr. Kersh was named manager of the company's Houston, Tex., office and remained until 1947, when he was appointed manager of industrial sales at East Pittsburgh. Two years later he was promoted to manager of central station sales, from which position he comes to his new duties.

Clarence Lynn (A '38, M '43, F '50), manager, D-C Generating Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed engineering manager of the atomic power division. Mr. Lynn was graduated from the University of Kansas in 1918 with a bachelor of science degree in electrical engineering. later entered the Power Engineering Department as a designer of d-c motors and generators. In 1928 he was made section engineer in charge of the design of d-c motors and generators. When the transportation and generator division was formed in 1938, he was made manager of the D-C Engineering

Department. In 1941, he was awarded the Westinghouse Order of Merit for his outstanding engineering accomplishments. Mr. Lynn has served the Institute on the following committees: Marine Transportation (1942–46, 1948–51); Rotating Machinery (1947–51).

E. M. Haacke (A '45), editor, *Electrical News and Engineering*, Toronto, Ontario, Canada, has been appointed Montreal branch manager, J. A. Wilson Lighting and Display Limited, Montreal, Quebec, Canada. Mr. Haacke is a graduate of Queen's University and his experience includes association with The Bell Telephone Company of Canada as a transmission engineer and as assistant editor and then editor of *Electrical News and Engineering*. During World War II, Mr. Haacke served as a radar officer in the Royal Canadian Air Force.

R. B. Bodine (A '37, M '45), sponsor engineer, central station engineering division, General Electric Company, Schenectady, N.Y., has been made manager of the large generator and converter sales division of the large motor and generator divisions. Mr. Bodine was graduated in 1936 from the University of Michigan with a bachelor of science degree in electrical engineering and mathematics. That same year he joined General Electric, and after three years in the company's advanced course in engineering, he was transferred to the central station engineering divisions. Mr. Bodine is also a member of Sigma Xi and Tau Beta Pi.

R. F. Field (M '40), engineer, General Radio Company, Cambridge, Mass., has retired after 21 years of service. Prior to his association with the General Radio Company, Mr. Field was a member of the faculty of Harvard University, Cambridge, Mass. He is well known for his work in impedance standardization, electrical measurements, particularly with bridge circuits, and the study of dielectric materials. Mr. Field, is a fellow of the Institute of Radio Engineers and the American Association for the Advancement of Science, and a member of the American Society for Testing Materials, the American Physical Society, Phi Beta Kappa, and Sigma Xi.

C. H. LeVee (M '42, F '50), sales manager, Wire and Cable Department, Eastern Division, United States Rubber Company, New York, N. Y., has accepted the position of Vice-President and chief engineer, Fagan Electric Company, Little Rock, Ark. He will also serve on the Board of Directors of Fagan Electric Company. Mr. LeVee is a graduate electrical engineer, having received his degree from Rensselaer Polytechnic Institute in 1924. Mr. LeVee is also a member of the American Military Engineers. In his new position, Mr. LeVee will have charge of all engineering and construction activities of the Fagan Electric Company.

J. L. Cox (A '46), chief engineer, Lamp Division, Duro-Test Corporation, North Bergen, N. J., has been appointed Vice-President in charge of manufacturing and engineering of its reactivated Electronics Division. Duro-Test Corporation curtailed its electronics subsidiary shortly after the end of World War II. The division is now being reorganized to contribute to the government's electronics defense program. Mr. Cox is regarded as an industry authority on gaseous discharge and electronic devices. He has several electronic inventions to his credit including the mercury bomb, the double cathode, and others.

R. E. Anderson (M '41), Vice-President, Delta-Star Electric Company, Chicago, Ill., has been named Senior Vice-President. In addition to his new duties Mr. Anderson will continue to direct the company's entire sales activities and commercial relations. His association with the Delta-Star Electric Company began in 1920 and he has advanced in the organization through positions as assistant sales manager, sales manager, and Vice-President. **C. S. Beattie** (M '40), Vice-President, Engineering Department, Delta-Star Electric Company, Chicago, Ill., has been appointed Executive Vice-President and general manager. In his new position Mr. Beattie will be in charge of all activites of the company. He joined the company in 1930 as sales engineer, and has successively been assistant sales manager, manager of engineering, and Vice-President in Charge of Production and Engineering.

E. S. Van Nostrand (M '46), operating superintendent, Southwestern Public Service Company, Amarillo, Tex., has been appointed manager of system planning for The West Penn Electric Company, New York, N. Y. Mr. Van Nostrand is a graduate of Lehigh University, class of 1925, with a degree of mechanical engineer. His previous experience includes association with the Philadelphia Electric Company and Pennsylvania Power and Light Company. From 1942 to 1945 he was with the War Production Board in the Power Supply Section of the Office of War Utilities. Mr. Van Nostrand is also a member of The American Society of Mechanical Engineers.

W. P. Shreve (A '45), manager, transmission line material sales, General Electric Supply Corporation, Bridgeport, Conn., has been appointed assistant manager of the Pittsburgh District. Mr. Shreve joined the company at Oklahoma City in 1938 and became branch manager at Amarillo, Tex., two years later. In 1948 he was transferred to the general office at Bridgeport, and subsequently became assistant manager of power apparatus sales. He has been manager of transmission-line material sales since 1949.

S. S. Wolff (M '43, F '50), chief engineer, Century Electric Company, St. Louis, Mo., has resigned this position to become associated with the American Safety Table Company, Reading, Pa., in the capacity of chief engineer. Mr. Wolff graduated from the University of Illinois in 1922 with a bachelor of science degree. His previous experience includes association with the American Electric Motor Company, as chief engineer, and with the Burke Electric Company, Erie, Pa., in the same capacity. In 1940 Mr. Wolff joined the Century Electric Company as assistant chief engineer and three years later became chief engineer. He is currently serving the Institute on the Rotating Machinery Committee.

P. F. Loftus (A '22, M '25), President, Peter F. Loftus Corporation, Pittsburgh, Pa., has been awarded an honorary doctorate degree in engineering by the University of Ottawa, Canada. He was graduated from the University of Ottawa in 1911, and he also holds an honorary doctor of laws degree which was conferred in 1939. Mr. Loftus has designed power plants for municipalities both in this country and abroad. He is also a member of the American Mining Congress, National Society of Professional Engineers, and Pennsylvania Society of Professional Engineers.

E. J. Rahill (A '32, M '48), division plant engineer, New York Telephone Company, Buffalo, N. Y., has been appointed Director of Technical Advisers on the Civil Defense Staff for Buffalo and Erie County. The duties of this post include liaison between the civil defense organization and the Technical Societies Council in order to obtain the assistance of outstanding men in technical and scientific fields, whenever their services are required for civil defense. Mr. Rahill was previously engaged in civil defense work during World War II.

R. W. Sorensen (A '07, F '19, Member for Life), professor of electrical engineering, emeritus, California Institute of Technology, Pasadena, Calif., has been notified of his election as an honorary member of the Institute of Electrical Engineers of Japan. Doctor Sorensen is a past President of the AIEE (1940–41), and has been very active in Institute affairs. He is at present serving the Institute on the following committees: Code of Principles of Professional Conduct; Members-for-Life Fund; Professional Division Advisory; and Registration of Engineers. Doctor Sorensen is also a member of the Engineers Joint Technical Society of Los Angeles, Calif., Sigma Xi, and Tau Beta Pi.

M. S. McIlroy (M '36), professor of electrical engineering, Cornell University, Ithaca N. Y., has been awarded the John M. Goodell Prize for 1950 by the American Water Works Association. The certificate and cash award are given to the member who has made the most notable contribution to the science of water works development during the year. Doctor McIlroy was cited for the development of an electric apparatus to study pressure flows in pipeline networks. He was graduated from Cornell University in 1923 with a bachelor of science degree in electrical engineering, and received a doctor of science degree from the Massachusetts Institute of Technology in 1947. Doctor McIlroy is a member of the American Society for Engineering Education, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi. He is currently serving the Institute on the Computing Devices Committee.

C. V. Roseberry (A '47), supervisor, central station division, Westinghouse Electric Corporation, Los Angeles, Calif., has been appointed manager of the Central Station De-

partment. Mr. Roseberry received his bachelor of science degree in electrical engineering from Oklahoma Agricultural and Mechanical College in 1934. Following graduation he joined the Westinghouse Electric Corporation and in 1936 was assigned to the San Francisco, Calif., office of the company as a central station salesman. In 1947 he was named assistant central station manager for the Pacific Coast District, and two years later was appointed central station supervisor for the Los Angeles branch territory.

Roland Whitehurst (A '20, F '43), Vice-President, Electric Storage Battery Company, Philadelphia, Pa., has been named a Director of the firm. He was born in Manchester, England, in 1893, and joined the company in 1908. In 1920 he was appointed as manager of the company's Washington, D. C., sales branch office and in 1940 he was named assistant general sales manager. His appointment as Vice-President in charge of sales followed in 1948. Mr. Whitehurst served the Institute on the Board of Examiners (1950–51). He is also a member of the Franklin Institute, American Society of Naval Engineers, and the Society of Automotive Engineers.

H. G. Michell (A '20, F '49), general manager, Bolivian Power Company, Ltd., La Paz, Bolivia, is retiring and **L. M. Howe** (A '37), assistant general manager, is succeeding Mr. Michell as general manager of the company. Mr. Michell is a graduate in electrical engineering from the University of Manitoba. He joined the staff of Bolivian Power Company, Ltd., in 1939. Mr. Howe was graduated from the University of Manitoba with a degree in electrical engineering and he obtained his master's degree at McGill University. He became associated with the Bolivian Power Company in 1942 as superintendent of the La Paz Division, and was operating engineer and assistant general manager before he was appointed to his new position.

E. R. Moore (M '40), assistant chief engineer, Engineering Department, The Detroit Edison Company, Detroit, Mich., has been elected the new President of Tau Beta Pi. Mr. Moore received a bachelor of science degree in electrical engineering from the University of Pennsylvania in 1920. He was associated with the General Electric Company for five years and then in 1926 he joined The Detroit Edison Company. Mr. Moore is also a member of Eta Kappa Nu.

C. W. Schweers (A '37, M '47), New England regional manager, Allis-Chalmers Manufacturing Company, Boston, Mass., has been named director of sales of the company's general machinery division. Mr. Schweers joined Allis-Chalmers in 1930 and has been connected with the company's general machinery division sales organization for more than 20 years. **M. M. York** (A '43), manager, Boston district office, Allis-Chalmers Manufacturing Company, Boston, Mass., has been named manager of the New England region. Mr. York became associated with Allis-Chalmers in 1939, and was a salesman in the Charlotte, N. C., district office for nine years before becoming manager at Boston.

G. M. Albrecht (M '17), patent attorney-in-charge, mechanical section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named special assistant to the general patent attorney. Mr. Albrecht was graduated from the University of Minnesota with an electrical engineering degree, and he received a law degree from George Washington University. Mr. Albrecht was employed as an examiner of patents in the United States patent office before joining Allis-Chalmers in 1918. He left the company in 1931 to practice patent law privately, but returned in 1946.

Joseph Chedaker (A '43), associate research engineer, Moore School of Engineering, University of Pennsylvania, Philadelphia, Pa., has joined the staff of the research division of the Burroughs Adding Machine Company, Philadelphia, Pa., as a research engineer. Mr. Chedaker was graduated from the University of Pennsylvania with the degree of bachelor of science in electrical engineering, and has been engaged in radio and electronic work since that time. He is also a member of the Institute of Radio Engineers and the Association for Computing Machinery.

F. P. Brown (A '44), electrical engineer, Midlothian, Ill., has joined the staff of the National Bureau of Standards as chief of the technical services section of the Ordnance Development Division. Mr. Brown received his bachelor of science degree in electrical engineering from the University of Michigan in 1932. His experience includes association with Commonwealth and Southern Corporation; Bechtel McCone Corporation; and The Pullman Standards Car Manufacturing Company.

A. M. Musgrove (A '30, F '45), Lieutenant-Colonel, United States Army, Dallas, Tex., has been promoted to the rank of Colonel in the United States Air Force. Colonel Musgrove is Director, Installations Engineering School, United States Air Force Institute of Technology. It is the purpose of the school to train Air Force officers to be management engineers of air bases. He served the Institute on the Transfers Committee (1947–48).

OBITUARY • • • • • •

Chester William Rice (A '13, M '26, F '39, Member for Life), retired, Boston, Mass., died on March 8, 1951. He was born on December 16, 1888, in Lynn, Mass. He received his bachelor of science degree in 1910 and his master's degree in electrical engineering in 1911 from Harvard University. Mr. Rice joined the General Electric Company that same year and was associated with the company until his retirement a few years ago. Mr. Rice was connected with the Consulting Engineering Department and had specialized in a number of fields, including sonic research. In 1932 he demonstrated a sonic locator which warned pilots of ships of fog-screened obstacles. Mr. Rice also invented a sonic altimeter which worked on the same principle, giving planes their distance above ground. He worked on submarine detectors, radar, and radio, holding a number of patents in these fields. Mr. Rice was an active member of the Institute, having served on the following committees: Education (1916–19); Electrophysics (1918–27); Communications (1922–28); Research (1928–33, Chairman 1932–33); Technical Program (1932–33); National Research Council, Division of Engineering (1932–35); Award of Institute Prizes (1932–33). Mr. Rice was also a fellow of the American Association for the Advancement of Science, the Acoustical Society of America, the American Physical Society, and the Institute of Radio Engineers; and a member of the Optical Society of America and the American Chemical Society.

George Albert Pierce (A '03, Member for Life), electrical engineer, retired, Philadelphia, Pa., died March 10, 1951. He was born on August 29, 1871, in Chester, Pa., and attended Drexel Institute. In 1895 Mr. Pierce became associated with the firm of William Cramp and Sons Ship and Engine Building Company, Philadelphia, Pa., as an electrical draftsman and became chief engineer in 1907. He developed and was granted patents for a system of submarine propulsion control from the conning station, for thermostats for use on shipboard, fire alarm systems, and several other devices. At the beginning of World War II, Mr. Pierce became principal electrical engineer associated with the Supervisor of Shipbuilding, United States Navy Inspector of Ordnance, New York, N. Y., and was responsible for the design and construction of electrical installations in many Naval vessels. He was a recipient of the Meritorious Civilian Service Award from the Navy Department in recognition of his services. Mr. Pierce was an active member of the Institute; he was one of the principal sponsors in the formation of the AIEE Committee on Marine Transportation and was a member of the committee from 1914–1942, and served as chairman, 1922–24, and 1926–27. He also served on the Meetings and Papers Committee (1922–24, 1926–27).

Frederic Streeter Brown (A '12, M '27, F '45, Member for Life), electrical engineer, Duquesne Light Company, Pittsburgh, Pa., died on March 4, 1951. He was born on February 9, 1886, in Lenox, Mass., and was graduated from Worcester Polytechnic Institute in 1908 with a degree of electrical engineer. After holding several positions in the power field, Mr. Brown joined the Duquesne Light Company in 1913 as a design engineer. For many years he was in charge of all substation and power station electrical design for the company. In 1945, he was named electrical engineer in charge of the Electrical Engineering Department and was responsible for all electrical engineering functions, and direction of the electrical station, transmission, distribution, customer services, and general engineering divisions. Mr. Brown served

the Institute on the Electrical Machinery Committee (1944–47) and the Transportation Committee (1947–51). He was also a member of the Engineers' Society of Western Pennsylvania.

Robert Dale McCarter (A '99, M '09, Member for Life), consulting electrical engineer, New York, N. Y., died on March 9, 1951. Born in Emporia, Kans., on September 10, 1872, he was graduated in 1895 from Ohio State University with a degree of mechanical engineer in electrical engineering, and practised as a consulting engineer in the United States and Europe. He joined the General Electric Company in 1895 and in 1902 accepted the position of general manager and engineer to the Bath Electric Tramways Limited in England. Mr. McCarter's experience as a consulting engineer was extensive and included association with the London office of the General Electric Company, the European Westinghouse Electric Corporation, and the Westinghouse Russian Electric Society as President and managing director. From 1936 he was consulting engineer for large public utilities departments in Spain and Egypt. He was Vice-President of the European Gas and Electric Company of London and New York from 1930 to 1934. Mr. McCarter served on the War Production Board from 1942 to 1945. Later he was Executive Vice-President of American Chrome and Magnesium Industries, Inc., Seattle, Wash.

Jerome Douglas Burbank (A '26, M '34), electrical engineer, Worthington Pump and Machinery Corporation, died February 6, 1951. Mr. Burbank was born in Toronto, Ontario, Canada, on July 13, 1897, and was graduated from the University of Toronto in 1925 with a degree of bachelor of applied science. After graduation Mr. Burbank became associated with the Niagara, St. Catherine's, and Toronto Railway as a student engineer. In 1929 he assumed the position of acting engineer in charge of the carrier current telephone system of the Niagara Lockport and Buffalo Niagara and Eastern Power Systems. Mr. Burbank became employed by the Worthington Pump and Machinery Corporation in 1949. He was also a member of the Engineering Institute of Canada, the American Military Engineers, and the Institute of Radio Engineers.

Frederick Sawtelle Jones (A '14, M '41, Member for Life), staff engineer, Lubricating Oil Department, Socony Vacuum Oil Company, Inc., New York, N. Y., died on February 26, 1951. He was born on July 6, 1892, in Augusta, Me., and was graduated from the University of Maine in 1914 with a bachelor of science degree in electrical engineering. From 1914 until 1929 Mr. Jones was associated with the General Electric Company where he became a turbine specialist. In 1929 he became manager of the New England Division of the Technical Department of the Vacuum Oil Company. In 1932 when the company merged with the Socony Vacuum Oil Company Mr. Jones' title was changed to chief engineer. He was also a member of the Engineering Society of New England.

Jacobus Kappeyne (M '18), consulting engineer, Brooklyn, N. Y., died on February 22, 1951. He was born on August 3, 1882, in Amsterdam, The Netherlands, and was graduated from the Polytechnikum of Zurich, Switzerland, as a mechanical engineer. He came to the United States in 1905, became a naturalized citizen, and worked as a consulting engineer in New York City until his death.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners at its meeting of March 15, 1951, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Fellow

Chambers, C. C., acting dean; supervisor of research, Moore School of Electrical Engg., University of Pa., Philadelphia, Pa.
Cox, F. A., asst. to elec. engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Ferri, L. F., supervisor, relay application, Commonwealth Associates, Jackson, Mich.
Gilbert, J. J., submarine cable engr., Bell Telephone Labs., Inc., Murray Hill, N. J.
Greenfield, E. W., senior development engr., Kaiser Aluminum & Chemical Corp., Newark, Ohio
Hansell, C. W., research supervisor, RCA Laboratories Div., Rocky Point, N. Y.
Hutcheson, J. A., vice pres.; director of research, Westinghouse Research Laboratories, East Pittsburgh, Pa.
Leerburger, F. J., consulting engr., 250 E. 43rd St., New York, N. Y.
Maxwell, M. V., asst. engr. & service mgr., Westinghouse Electric Corp., Chicago, Ill.
Molina, E. D., mathematics lecturer, Newark College of Engineering, Newark, N. J.
Noest, J. G., div. engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Rankin, H. M., vice pres. & chief engr., Metropolitan Edison Co., Reading, Pa.
Shelleng, J. C., radio engr., Bell Telephone Laboratories, Inc., Deal, N. J.

13 to grade of Fellow

To Grade of Member

Abright, W. F., partner, Abright Electric Co., Dallas, Tex.
Adler, H. A., senior engr., Commonwealth Edison Co., Chicago, Ill.
Atkins, J. W., college instructor, Weber College, Ogden, Utah
Benckenstein, R. J., assignment engr., General Electric Co., Richland, Wash.
Benjamin, A. S., chief, sales methods div., Teletype Corp., Chicago, Ill.
Booth, C. E., elec. engr., Westcott & Mapes, Inc., New Haven, Conn.
Brashurger, R. A., laboratory engr., Chrysler Corp., Highland Park, Mich.
Brauch, H. N., design engr., Westinghouse Electric Corp., Sharon, Pa.
Burnett, W. C., div. transmission & protection engr., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Clevenger, C. M., elec. engr., Southern California Edison Co., Los Angeles, Calif.
Deaster, J. F., mgr., elec. section, Product Engineering Laboratory, Dow Corning Corp., Midland, Mich.
Faber, C. W., co-ordinating elec. engr., Brazilian Traction Group, Rio de Janeiro, Brazil
Fillmer, H. H., operation supt., Sho-Me Power Corp., Marshfield, Mo.
Foster, W. P., application & development engr., James G. Biddle Co., Philadelphia, Pa.
Hartnack, E. W. C., product section engr., Line Material Co., Zanesville, Ohio
Hedges, R. E., elec. engr., Douglas Aircraft Co., Santa Monica, Calif.
Horning, R., office mgr., General Electric Co., Charlotte, N. C.
Iyengar, K. R., chief engr., Kaycee Industries, Ltd., Bombay, India
Kelling, L. U. C., application engr., General Electric Co., Schenectady, N. Y.
Kerr, M. B., senior engr., Western Union Telegraph Co., New York, N. Y.
Kunko, A., asst. prof. of elec. engg., Massachusetts Institute of Technology, Cambridge, Mass.
Malkin, A., asst. chief plant engr., Canadian Car & Foundry Co., Ltd., Montreal, Quebec, Canada
Miller, M. V., electronics engr., Philadelphia Naval Shipyard, Philadelphia, Pa.
Mumma, R. E., mgr., Electronics Research Lab., National Cash Register Co., Dayton, Ohio
Ort, H. A., elec. engr., Packard Electric Co., St. Catherines, Ontario, Canada
Parker, M. C., elec. engr., Bonneville Power Administration, Portland, Oreg.
Peabody, E. P., section elec. engr., General Electric Co., Richland, Wash.
Perrin, W. G., associate elec. engr., City of Glendale, Calif.
Raines, W. A., sales engr., General Electric Co., New York, N. Y.
Rebholz, J. T., Jr., 45–55 Parsons Blvd., Flushing, N. Y.
Roberson, D. A., elec. engr., Ebasco Services, Inc., New York, N. Y.
Savage, P. L., mgr. engg. div., General Electric Co., Los Angeles, Calif.
Sawyer, S. P., elec. engr., Fitchburg Gas & Electric Light Co., Fitchburg, Mass.
Schultheiss, C. E., development engr., S & C Electric Co., Chicago, Ill.
Smith, W. L., development engr., The Electric Controller & Mfg. Co., Cleveland, Ohio
Treffeisen, R. E., requisition engr., General Electric Co., Schenectady, N. Y.
Vanaman, L. L., elec. engr., Knoxville Utilities Board, Knoxville, Tenn.
Vaughan, J. T., works mgr., tocco div., The Ohio Crankshaft Co., Cleveland, Ohio
Watt, D. H., pres., Watt Plumbing, Airconditioning & Electric, Tulsa, Okla.
White, M. F., chge. design & constr., Haydu Bros., Plainfield, N. J.
Yarbrough, C. T., mgr., electric service, Westinghouse Electric Corp., East Pittsburgh, Pa.

41 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before May 25, 1951, or July 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Brown, J. J. W., General Elec. Co., Schenectady, N. Y.
Coker, A. L., c/o William Jacks & Co. (Malaya) Ltd., Singapore, S. S.
Cook, R. A., 5130 Arcade Bldg., Seattle, Wash.
Cully, J. F., University of California, Los Alamos, N. Mex.
Dickerson, F. W., Graybar Elec. Co., New York, N. Y.
Doede, H. O., Pioneer Service & Engg. Co., Chicago, Ill.
Friede, H. A. (re-election), Dist. of Columbia Govt., Washington, D. C.
Ganguli, S. C., Indian Post & Telegraph Workshops, Calcutta, India
Gesell, W. B., Oklahoma Gas and Elec. Co., Oklahoma City, Okla.
Gibson, A. C., Nashville Elec. Service, Nashville, Tenn.
Gordon, M. F., Brown University, Providence, R. I.
Graham, H. C., Northern Elec. Co. Ltd., Toronto, Ontario, Canada
Hartley, H., The General Elec. Co. of India, Ltd., Bombay, India
Harvey, J. H. (re-election), U.S.B.R., Davis Dam, Nev.
Healy, E. S. (re-election), Ebasco Services, Inc., New York, N. Y.
Hirsch, L. H., Century Elec. Co., St. Louis, Mo.
Horn, L. H., Underwriters Labs. Inc., Chicago, Ill.
Houdek, J. F., Jr., Kellogg Switchboard & Supply Co., Chicago, Ill.
Jones, E. D., 121 E. 3rd St., Charlotte, N. C.
Knecht, A. W., Seelye, Stevenson, Value & Knecht, New York, N. Y.
Lanford, C. C., Commission of Public Works, Greer, S. C.
Lynch, P. G. (Miss), Automatic Elec. Co., Chicago, Ill.
Maddox, J. A. M., Byck Elec. Co., Savannah, Ga.
Marquardt, J. W., 3321/2 E. Adams St., Springfield, Ill.
Patterson, I. S., English Elec. Co. of Canada, Ltd., St. Catharines, Ontario, Canada
Rao, S. P., The Fertilisers & Chemicals, Travancore Ltd., Alwaye, S. India
Revesz, G. L., Compagnie des Mines de Huaron, San Jose por Shelby, Peru, S. A.
Richardson, R. B., Ebasco Services Inc., New York, N. Y.
Roach, F. J., Radio Corp. of America, Camden, N. J.
Short, W. E., Collins & Gould, Tulsa, Okla.
Slick, E. P., Capehart Farnsworth Corp., Ft. Wayne, Ind.
Smith, W. J., Commonwealth Edison Co., Chicago, Ill.
Strate, M. E., Geneva Steel Co., Geneva, Utah
Tench, A. O., Federal Power Comm., Chicago, Ill.
Tsang, N. F., University of Minnesota, Minneapolis, Minn.
Walsh, R. N., International Tel. & Tel. Corp., New York, N. Y.
West, R. H., University of California, Berkeley, Calif.
Wojciechowski, B. M., Western Elec. Co., Inc., Kearny, N. J.

38 to grade of Member

OF CURRENT INTEREST

Methods of Radio Astronomy Used to Study Total Eclipse

The National Bureau of Standards (NBS) participated in an expedition to Attu Island, Alaska, to observe the total eclipse of the sun by the moon on September 11, 1950. The expedition was organized primarily to apply the methods of radio astronomy to the study of the eclipse at various radio frequencies.

In addition to infrared, visible, and ultraviolet radiation, the sun is continually giving off energy at radio frequencies. In recent years, the techniques of radio astronomy have been developed for receiving and analyzing these longer wavelengths. This has made it possible to obtain information about the positions of stellar bodies and matter in interstellar space that could never have been seen with an optical telescope.

The path of the total eclipse crossed United States territory only on Attu, a small piece of land, the last and most westerly of the Aleutian chain. While the climate of Attu is most undesirable for making visual observations with an optical telescope, it seemed likely that significant results could be obtained there with radio apparatus.

The high-frequency energy from the sun was collected by a mirror ten feet in diameter having a focal length of three feet. An alti-azimuth mounting made it possible to sight the mirror on the sun. The mirror served to focus the incoming radiation on an antenna placed at its focal point and connected to a high-frequency receiver. Signals thus received were amplified and applied to an automatic recorder, providing charts of intensity versus time for various frequencies.

Measurements of solar radio intensity were made at wavelengths of 3, 10, and 65 centimeters. The receiving equipment for

Apparatus operated by the NBS on the Alaskan eclipse expedition. High-frequency radio waves from the sun were collected by the 10-foot radar mirror and focused on the antenna of a high-frequency receiver. Signals thus received were amplified and applied to an automatic recorder, providing charts of intensity versus time

use at the 65-centimeter wavelength, which was supplied and operated by the NBS, was a superheterodyne receiver having a 30-megacycle intermediate frequency and two stages of radio-frequency amplification. The measurements were made from two to four times a minute beginning about two hours before the eclipse. The sky at an azimuth of about 90 degrees from the sun was used as zero reference. The sun was found to be quiescent and reasonably free from the transients which are often present during periods of solar activity.

Because of the radio waves sent out by the sun's ionized atmosphere, the apparent diameter of the sun at radio frequencies is always appreciably greater than at visual wavelengths. Consequently, all solar eclipses "viewed" with radio apparatus must appear to be annular rather than total. Preliminary results obtained from analysis of the data indicate that the apparent diameter of the sun exceeds that of the moon by 3, 7, and 11 per cent respectively at wavelengths of 3, 10, and 65 centimeters.

Besides the ionized atmosphere of the sun, a variety of other solar phenomena are effective in generating radiation at radio frequencies. For example, the magnetic field associated with sun spots causes additional radiation at centimeter wavelengths to originate in the neighborhood of the spots. Thus, as the edge of the moon first covered and later uncovered a spot group near the center of the solar disk, the observed intensity at radio frequencies dropped sharply and then rose again.

If the radio-frequency brilliance of the solar corona had been symmetrical, a minimum of observed intensity should have occurred at the time of optical totality. Actually, however, the minimum occurred a few minutes after totality at all three wavelengths. This was probably due to assymmetry of the corona caused by a group of spots near the east limb of the sun.

When the edge of the moon appeared just to touch the edge of the sun and at the instant when the edge of the moon finally left the edge of the sun, the apparent intensity rose about ten per cent above that of the unobscured sun. The explanation of this effect is not yet clear; it may be due to reflections of solar energy from the surface of the moon at grazing incidence. Diffraction around the edge of the moon could not have been the cause, as waves of kilometer rather than centimeter length would have been required. The possibility that this unexpected rise in intensity might have been caused by reflections from the landscape near the apparatus is under investigation.

Future Meetings of Other Societies

American Materials Handling Society. Materials Handling Conference held concurrently with the National Materials Handling Exposition. April 30–May 4, 1951, International Amphitheatre, Chicago, Ill.

American Society for Quality Control. Fifth National Convention. May 23–24, 1951, Hotel Cleveland, Cleveland, Ohio.

American Society for Testing Materials. Annual Meeting. June 18–22, 1951, Atlantic City, N. J.

Compressed Air and Gas Institute. June 7–8, 1951, Seaview Country Club, Absecon, N. J.

Conference on Industrial Research. Second Annual Meeting. June 11–15, 1951, Department of Industrial Engineering, Columbia University, New York, N. Y.

Edison Electric Institute. 19th Annual Convention. June 5–7, 1951, Denver, Colo.

Greater New York Industrial Show. Sponsored by the Technical Societies Council. May 7–11, 1951, 71st Regiment Armory, 34th Street and Park Avenue, New York, N. Y.

Illuminating Engineering Society. Great Lakes Meeting. May 24–25, 1951, Hotel Gibson, Cincinnati, Ohio.

Institution of Electrical Engineers. Conference on Electrical Instrument Design. May 28–31, 1951, The Institution Building, London, England.

National Conference on Airborne Electronics. Sponsored jointly by the Professional Group on Airborne Electronics and the Dayton Section of the Institute of Radio Engineers. May 23–25, 1951, Biltmore Hotel, Dayton, Ohio.

Society of Motion Picture and Television Engineers. Spring Convention. April 30–May 4, 1951, Hotel Statler, New York, N. Y.

Society of the Plastics Industry, Inc., Annual National Meeting. May 24–25, 1951, Greenbrier Hotel, White Sulphur Springs, W. Va.

The American Society of Mechanical Engineers. Semiannual Meeting. June 11–15, 1951, Royal York Hotel, Toronto, Ontario, Canada.

First Television Antennas Installed on Empire State Building Mast

Completion of the installation of the five television antenna arrays on the 222-foot mast atop the Empire State Building (*EE, Jan '51, p 2*) has been delayed because of the adverse weather conditions existing for 44 out of the 65 working days since January 1st above the 1,250-foot level at the base of the tower. As the work is being done from the top downward, the first transmitter to go on the air will be WNBT after the installation of the coaxial cable, automatic de-icing devices, and various cables, and after the completion of the operating tests. The other four stations are expected to begin transmissions

Electrician working on one of the television antenna units of the turnstile array on the Empire State Building tower topmost pole. The coaxial cable is inside the pole, which also contains power cables for de-icing the antennas

One of the turnstile antennas being hoisted to the WNBT section of the television tower on top of the Empire State Building. The 6 1/8-inch copper coaxial cable will be run through the circular openings in the platform gratings; power cables will be run inside the angle-members at the tower corners

at approximately monthly intervals as their installations are tested.

In discussing the million-dollar project, Dr. Frank G. Kear, consulting engineer of the project's primary committee, stated that the antennas of two more television transmitters could be accommodated on the tower and that these antennas could be installed at a later date without interrupting the transmission of the five other stations.

While work on the tower and antennas has been progressing, three television transmitters have been installed on the 89th and higher floors of the building and work on two more has been started. When the five stations are transmitting simultaneously, no one station will have any advantage over any of the others because of its antenna's relative position on the tower; each station will have the same opportunity to cover the same area with the same signal strength.

New Push-Button Communication Center Replaces Manually Controlled System

The electric impulse which turned on the new push-button communication center at American Steel and Wire Company, Cleveland, Ohio, was obtained by the fusing of a wire suspended above an iron trough at one of the company's Cleveland blast furnaces. The private telegraph switching center will speed the flow of messages between 149 United States Steel plants and offices in 86 cities. The new center replaces a manually controlled center which has been in use for many years.

The electric impulse which turned on the equipment was obtained by placing a loop of fusible wire 12 inches above an iron trough. After the furnace was cast, hot iron flowed through the trough at a temperature of 2,650 degrees and melted the wire loop. This broke an electric connection, activating a relay, which in turn pushed a button energizing the telegraphic apparatus.

The push-button center gets its name from the fact that the time and effort of switching an incoming telegram to its destination is reduced, by means of complex equipment, to the simple expedient of pressing a button. The new apparatus replaces the old cord-and-plug type of operation.

Through the new system, each message is typed only once on the typewriter-like keyboard of a teleprinter at the originating point, and flashes to the center. There an operator observes the destination on a perforated tape, touches the proper button, and an electric "brain" flashes the message over a circuit leading to its destination.

One feature in the new service of the new center is a master push-botton panel by which a telegram can be transmitted simultaneously to numerous offices and plants.

A printer perforator receives the signals from an incoming circuit and prepares the tape with printed characters on the upper edge and perforated combinations representing letters directly below. Each printer perforator has an associated transmitter which can be connected with any outgoing circuit in the center by means of the push-button.

A vigilant monitor system protects the center against any failures. Associated with each telegraph circuit is an automatic "remembering" machine—a message-numbering device which transmits a group of letters identifying the center at which the switch is made and the station to which the message is being routed. This machine inserts an identifying channel number prior to the transmission of each message.

An additional safeguard is a group of

The electric impulse which turned on the new push-button communication center at American Steel and Wire Company, Cleveland, Ohio, was obtained by the fusing of a wire suspended above the iron trough at one of the company's blast furnaces. This broke a connection, activated a relay, which in turn caused an "automatic finger," which is being indicated by Mr. H. B. Jordan, President, to energize the telegraphic apparatus

"diary printers" which automatically record the top line of every message transmitted through the center. This maintains a complete and continuous record, available for immediate reference at any time.

More than 270 miles of wiring and over 280,000 hand-soldered connections were involved in the installation of the new center.

Simple Gauge Performs Miracles of Measurement

A simple gauging device the size and thickness of a postage stamp can measure minute or extremely heavy loads, dimensional changes of 1×10^{-6} inch, or temperature changes ranging from near absolute zero to 1,600 degrees above. Mr. Francis G. Tatnall, Manager of Testing Research at Baldwin Locomotive Works, Philadelphia, Pa., described the instrument at the annual meeting of the American Society of Tool Engineers.

The simple device consists of a wire one-third the thickness of a human hair which is wound back and forth, then coated with cement. If the gauge is distorted so that the wire is stretched or contracted, its resistance to passage of an electric current is varied. Measurement of the variation tells the exact amount of stretch. The instrument will accurately measure a dimensional change of 1×10^{-6} inch in one inch of length.

One application of the gauge is in testing military jet engine blades while they are in operation. The gauge is cemented to the blade, a current passed through it, and the engine is run. Any bending of the blade stretches the wire and changes its conductivity, which then is registered on a meter. Thus the engineers can tell exactly what is happening to a spinning blade while the engine is in operation.

Conversely, to weigh the load on a bridge, the gauge is cemented to one of the supports. A change in load causes the support to give a slight amount. This is immediately registered by the gauge. Simple calculation then determines the exact load that caused the support to give.

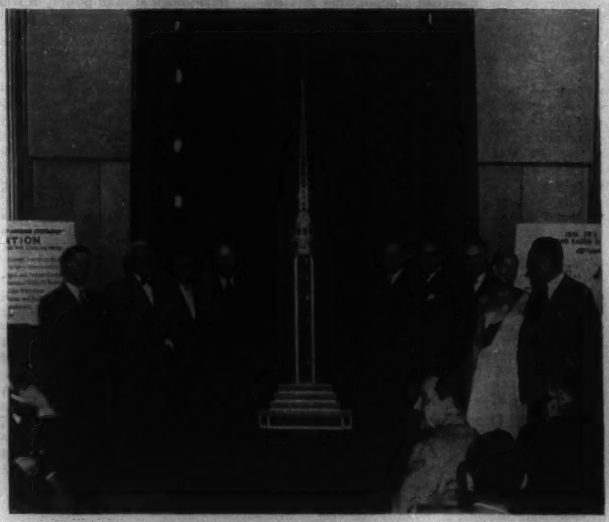
Stanford Studies Industrial Demand for Fission Products

New constructive, industrial uses for by-products of the atomic energy program, through the medium of large-scale employment of fission products, are being investigated on a nation-wide basis by Stanford Research Institute for the United States Atomic Energy Commission.

The immediate objectives of the study are to acquaint industrial concerns with the characteristics of fission products and to obtain the co-operation of industry in developing estimates of their possible utilization.

The atomic by-products known as "fission products" are a highly radioactive mixture of elements produced by the fission or splitting of uranium during the plutonium production process in nuclear reactors. These radioactive atoms have no usefulness for industrial or explosive power but only for the energetic radiations which they emit. Large quantities of fission products left over from plutonium processing now are stored in a mixture with contaminants in underground tanks at the Hanford, Wash., works.

As a result of this study, industry may be offered an opportunity to tap large-scale, low-cost sources of radioactivity. The cost should be substantially lower per unit of radioactivity than presently available sources. For example, the cost per curie of fission products in large quantities is estimated to be in the range of 0.01 to 0.001 of the price of most radioactive materials which are presently available.



Attending the unveiling of the 14-foot model of the Empire State Building television antenna mast at the Institute of Radio Engineers' Convention were: left to right, George Sterling, FCC Commissioner; Comdr. M. W. Lowei, Director, Du Mont TV network; Frieda Hennock, FCC Commissioner; Lt. Gen. Hugh Drum, Pres. Empire State Building, Inc.; Brig. Gen. David Sarnoff, Chairman of the Board, RCA; P. B. Stephens, business manager, N. Y. Daily News; E. M. Webster, FCC Commissioner; Kay Burke, "Miss Empire State"; E. J. Noble, Chairman of the Board, American Broadcasting Co.

New Radioisotope Service Offered at Brookhaven Laboratory

Special radioisotope distribution and irradiation services utilizing the new nuclear reactor at the Brookhaven National Laboratory at Long Island, N. Y., have been authorized recently by the Atomic Energy Commission (AEC).

The AEC laboratory at Brookhaven will specialize in the production of highly radioactive isotopes and short half-life isotopes that cannot be effectively shipped to the Brookhaven region from Oak Ridge, Tenn., or other distant locations.

Inquiries concerning the new Brookhaven services may be addressed to the Isotopes and Special Materials Group, Brookhaven National Laboratory, Upton, N. Y. Requests for radioisotopes or irradiation services should be made to the AEC Isotopes Division, Oak Ridge, Tenn.

Institute of Radio Engineers Holds 40th National Convention

The 40th annual convention of the Institute of Radio Engineers (IRE) was held on March 19–22, 1951, in New York, N. Y., with a registration of 18,000 members representing 31 countries. The annual Radio Engineering Show, with 279 exhibits of the latest electronic apparatus, was held at Grand Central Palace.

More than a third of the papers delivered at the meeting dealt with color television signal generation, transmission, reception, and the engineering aspect of color reproduction by television picture tubes.

Military items such as atomic piles, radar, guided-missile controls, and gun-laying computers were discussed. Communications and warning apparatus using electron tubes and needed for civilian defense received attention.

New Radio Attachment Eliminates Commercials

A new device which completely and automatically eliminates commercials from broadcast programs without losing a note of the music was described and demonstrated at the annual convention of the Institute of Radio Engineers (IRE). It contains in its present form only four ordinary radio tubes, and it can be attached to any existing set.

Invented and perfected by Dr. R. Clark

Jones of the Polaroid Corporation of Cambridge, Mass., this bit of modern electronic magic "listens" for a program's pauses and measures their abruptness, remembers how many have passed during the preceding seconds of the program, and makes its decisions accordingly. It can even distinguish between singing commercials and other music. The automatic commercial-silencer was evolved by Doctor Jones from the ever-broadening field of the electronic calculator.

It is completely automatic in operation when attached to a radio or television set. It is quite simple and reliable, but required months of research to produce. It makes use of five inherent functions of the ordinary electronic calculator—it extracts logarithms, it integrates values, differentiates, subtracts, and can "remember." Doctor Jones developed the device in his spare time, as a hobby.

New Device Used to Record Technical Data Simultaneously

A technique for recording simultaneously both the radioactivity and rock strata resistance in underground drilling operations and for other industrial and scientific applications was announced recently by the Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.

The new system consists of an electronic recording instrument for obtaining, in a single operation, data of great value in searching or drilling for oils, minerals, and water. The same device may also be used for spectrometer analyses and in meteorology for recording wind velocity and direction and to measure tide levels and currents simultaneously.

Previously, separate measurements have had to be taken for two sets of data by making two "passes," one up and one down. Now a 2-pen electronic recorder enables drillers to get the same results at greater speed and with a saving in man power. The simultaneous recordings of the new device require only one recording "pass," permitting speedy withdrawal of an entire electrode from a well.

The speeds of descent and ascent of drilling apparatus had to be equal under the old systems, causing frequent errors when a correlation of separate records was attempted. By the new method, the correlation is automatic.

Other applications for dual or simultaneous recording were said to include the measuring of effectiveness of mechanical coating process on a transparent film or other base. In this application one record will show the density of the coating of a product as it emerges from a process, the other shows density before coating, the arithmetical difference providing a quantitative measurement of coating density.

NAM Recommends that Civilians Advise on Mobilization

The appointment of an "essentially civilian" commission to advise President Truman and the Director of Mobilization on the continued supply and efficient use of technological man power, of which a critical shortage exists, is being recommended by the National Association of Manufacturers (NAM).

The ability of industry to meet defense or war production demands depends on an increasing flow of scientific and engineering graduates, it is emphasized in a current report by the association's Research Committee. It is pointed out in the report that there is already a shortage of engineers, and an impending shortage of 40,000 engineering graduates by 1954, even if none were drafted. The shortage of scientists in numerous fields is also critical. A particularly serious aspect of the technological man power shortage is that 25 per cent of the technically trained men in industry are reservists in the armed forces. Withdrawal of these men from industry is now entirely in the hands of the Department of Defense.

The committee recommends that ". . . an essentially civilian commission, comprised of men of established eminence and integrity and familiar with the role of technology in national affairs, should be appointed by the President to advise him and the Director of Mobilization from time to time on the supply and efficient utilization of technological man power, including those in military reserve status."

Function of National Inventors Council in the Defense Program

The National Inventors Council functions in an advisory capacity to the Department of Defense and other departments, agencies, and offices of the government in evaluating, guiding, and analyzing inventions for the national defense and security. The Council membership comprises outstanding American inventors, scientists, and industrial research men having specialized experience in the development and utilization of inventions, together with the Commissioner of Patents and a representative of each of the three branches of the Armed Services.

The Council was originally created in the fall of 1940 by the Secretary of Commerce with the concurrence of the President. During the war years the Council screened over 200,000 inventions for the Armed Services. Many of them played an important part in the war—the magnetic mine detector, for example. Since then the Council has continued to function in the Commerce Department in accordance with the recommendations of the Department of Defense.

Besides acting in an advisory capacity on questions of national security and welfare, the Council functions to encourage the public to submit inventions or inventive ideas of value in the defense and welfare of the nation and to acquaint the public with the problems confronting the Armed Services, and refers all potentially valuable ideas to the Department of Defense or other appropriate agencies.

No special forms are required for submitting proposals to the Council and the services of an attorney are not essential. Consideration of inventions is facilitated if each proposal is submitted as a separate document, preferably typewritten, containing complete information on the principles underlying the operation of the apparatus or invention together with a discussion of any tests which have been conducted and the particular points of novelty or superiority of the inventions as compared with existing devices or practices.

The following partial list of technical problems on which information is needed has been compiled by the National Inventors Council with the co-operation of the Armed Services. All of these technical problems affect national defense: To Provide for the Rapid Splicing of Assault and Field Type Wires; Snow Vehicle; Machinery for Fabrication and Method of Welding Titanium; Adhesive for Explosives; Adhesive Tape, Industrial; Automatic Coupling Joint; Lightweight Unicellular Foam Filler for Field Manufacture; Radical Methods of Ship Discharge; Snow and Ice Mole; A Personal Heating System; Practical Method of Destroying Tell-Tale Tracks of Men on Foot or Vehicles Across Snow Fields; Supply System for Use on Glaciers; Stabilization of Flat Surfaces; Inexpensive Method for Rapidly Converting Snow and Ice into Drinking Water in Quantity; Heating Clothing for Personnel in Low-Activity-Level Occupations; Material for Arctic Gloves Resistant to Deterioration by Oil and Gasoline; Device for Protection of Head and Respiratory Tract Against Cold; Engine and Personnel Heaters; Means of Individual Protection from Gamma Radiation; Method for Prolonging the Preservation of Whole Blood; Accurate Instrument and Technique for Barometric Leveling; Technique, Method, and Equipment for the Detection of Buried Explosives; Rapid, Automatic Methods of Determining the Size of Smoke Particles and the Obscuring Power of the Smoke.

Basically, these problems are distributed to find the best existing solutions and promising ideas which may lead to better solutions. Anyone who has such information is urged to communicate with the National Inventors Council, Department of Commerce, Washington 25, D. C.

All ideas and suggestions submitted to the Council are carefully screened. When a proposal appears to be constructive, the Council refers it to the appropriate technical branches of the Armed Services for study. The judgment of the Armed Services concerning the matter is communicated to the inventor as soon as possible.

It should be emphasized that these problems are not released in an attempt to find firms and organizations interested in obtaining development contracts from the Armed Services. Those concerns interested in development contracts should discuss the matter directly with the technical branch of the Armed Services in their field of specialization. What the National Inventors Council seeks to do is bring these problems to the attention of individual inventors, scientists, and engineers. Through this technique, their constructive thinking is applied to the technical needs of our Armed Forces.

Water Resources Policy Commission Report Completed

The President's Water Resources Policy Commission, which was appointed in January 1950 to study and make recommendations on policies in the field of water resources, together with existing legislation, has just released to the public the last of its 3-volume

report and, having completed its assignment, has gone out of business.

The Commission's main report, Volume 1, entitled "A Water Policy for the American People," offers a co-ordinated national program for the development of water resources, together with specific recommendations on policy. Volume 2, "Ten Rivers in America's Future," is a study of ten river basins in different parts of the country and includes a detailed discussion of the problems of each basin with a mass of pertinent material never heretofore published. Each of these basin studies has been published separately. The third volume, "Water Resources Law," summarizes Federal law concerned with the nation's water resources.

A 24-page pamphlet containing the Commission's summary of recommendations, reprinted from Volume 1, gives a concise idea of the scope and content of the report. Copies of each volume, the Summary of Recommendations, and the ten river-basin studies may be purchased from the Superintendent of Documents, Washington 25, D.C., at the following prices:

Volume 1: "A Water Policy for the American People"	$3.25
Volume 2: "Ten Rivers in America's Future"	6.00
Volume 3: "Water Resources Law"	2.25
Summary of Recommendations	0.15

The separate sections of Volume 2 may be had for prices varying from 50 cents to $1.00. The series includes the Columbia, Missouri, Rio Grande, Colorado, Connecticut, Alabama-Coosa, Potomac, Ohio, the Tennessee Rivers, and the Central Valley of California.

Detroit Edison Company Orders a Third New Steam Turbogenerator

The Detroit Edison Company has ordered a third 125,000-kw (166,000-horsepower) steam turbogenerator for its new St. Clair power plant. Two similar generators for the plant, now under construction on the St. Clair River front three miles north of Marine City, Mich., already are being built.

Capacity of the St. Clair generating station, as now planned, will be 375,000 kw—500,000 horsepower. When the new equipment is in full operation, late in 1953, maximum capacity of the Edison system's five plants will total about 3,000,000 horsepower, more than twice that of 10 years ago.

Excavation for the new St. Clair plant building has already begun, and pile-driving for the foundations is to start soon. Material for the foundations of the additional turbogenerator was included in the original construction plans and a supply of structural steel for the third unit is on order.

Symposium on Nuclear Engineering Will Be Held at Oak Ridge

The 1951 Summer Symposium in the series sponsored annually by the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies will be held from August 27 to September 6, 1951, at Oak Ridge, Tenn.

Sessions in the 1951 symposium will be devoted to nuclear engineering, at the request of the American Society for Engineering Education. Representatives of interested industrial organizations are invited to join the Atomic Energy Commission personnel and representatives of educational institutions in discussions of basic nuclear engineering, general nuclear power philosophy, applications of the engineering sciences to nuclear technology, and the problems of nuclear engineering education.

Inquiries concerning participation in the symposium should be addressed to Dr. Russell S. Poor, Oak Ridge Institute of Nuclear Studies, Post Office Box 117, Oak Ridge, Tenn.

New Ultrahigh-Frequency Transmitter Built by GE

Announcement has been made of the development of a new 5-kw ultrahigh-frequency television transmitter by the General Electric Company, Electronics Park, Syracuse, N. Y. The transmitter system will have an effective radiated power of 100 kw and will operate in the 500-megacycle region. This is made possible by the development of a new type of ultrahigh-frequency velocity-modulated 5-kw tube, and a new type of antenna which increases the effective radiated power by 20 times.

One section of the new type of television transmitting antenna developed by the General Electric Company which will be used for high power ultrahigh-frequency telecasting. The new antenna, which will be made up of four sections like the one shown, will increase the effective radiated power of the ultrahigh-frequency transmitter by 20 times

The General Electric Company has requested permission from the Federal Communications Commission to operate the ultrahigh-frequency transmitter on an experimental basis, and when granted, will make field reception tests.

Scientists Urgently Needed by the National Bureau of Standards

The National Bureau of Standards, Department of Commerce, urgently needs competent scientists in the fields of electronic science, engineering, and physics. Specialists in these fields in the Bureau will be engaged mainly in work which represents research and development needed by the Department of Defense. The work offers opportunities for professional growth and advancement and may often form the basis for a doctor's thesis.

The most urgent need for engineers and physicists is at starting salaries ranging from $4,600 to $8,800 a year.

Applications for scientific positions are being accepted by the United States Civil Service Commission, Washington 25, D. C., under Announcement *Number 226* for Physicist, Chemist, Metallurgist and Mathematician, and its amendment for Electronic Scientist. Details about the requirements of experience and/or education, as well as other requirements, are given in the announcement and amendment.

Applications may be obtained from most first- and second-class post offices, from Civil Service regional offices, or from the Commission's Washington office.

Radar Unit with 100-Mile Range Installed in Chicago, Ill.

A complete radar unit with a range of 100 miles is being installed at Illinois Institute of Technology, Chicago, Ill. The unit will be used in advanced electrical engineering courses to demonstrate principles and application of ultrahigh frequencies.

While the unit, one of the largest naval airborne types developed in World War II, could be used in civil defense, it was designed for land and water search.

The equipment, obtained through the War Assets Administration, is being installed on the roof of the Main building, 33rd and Federal streets, under the direction of Mr. Charles Benz, electrical engineering department technician, and Mr. Lewis Ebinger, department instructor.

Westinghouse Educational Foundation to Grant Fellowships

Between 20 and 40 fellowships, each valued at $250, will be awarded to secondary school science teachers who will participate in a special six weeks' summer program at Carnegie Institute of Technology, Pittsburgh, Pa. The fellowships have been made available by the Westinghouse Educational Foundation, which is maintained by the Westinghouse Electric Corporation.

The program of study will stress the im-

portance of fundamental concepts in chemistry, physics, and mathematics, and will provide a survey of recent developments in the pure and applied sciences. The academic program will consist of lectures on such topics as radioactivity, nuclear research, synthetic rubber, petroleum, and applied mathematics. It will be supplemented by visits to Carnegie Institute of Technology's research and teaching laboratories and to some of the industrial establishments of the Pittsburgh area.

The program will provide six hours of credit for teachers who are seeking credits for advanced degrees. Full-time staff members of the college of Engineering and Science will have charge of the course.

The program will begin Monday, July 2, and extend through Friday, August 10, 1951. Saturday sessions will be held. A tuition fee of $50.00 will be charged for the 6-week course and the balance of the $250.00 fellowships can be applied to commuting or living expenses. Living accommodations in Carnegie dormitories will be available at reasonable rates, and dining facilities are available on the campus. The school's recreational facilities will be available without charge to fellowship winners.

Application forms and further information about the summer program can be obtained from the Director of Admissions, Carnegie Institute of Technology, Pittsburgh 13, Pa.

Cornell to Offer Special Summer Program of Study

A special program of advanced study for teachers of engineering will be offered by the College of Engineering at Cornell University, Ithaca, N. Y., during the university's summer session July 2–August 11, 1951.

The six courses are intended for instructors in mechanics, structures, and similar subjects. They will be taught by members of the Cornell engineering staff and will provide opportunity for individual study of particular interest to the student.

Each course carries three hours' credit. Two may be taken during the session. Inquiries should be addressed to Professor Conway, West Sibley Hall, Cornell University, Ithaca, N. Y.

Brooklyn Polytechnic Institute Resumes Its Annual Open House

A decade of advancement in engineering and science was revealed to the public when the Polytechnic Institute of Brooklyn, N. Y., founded in 1854, opened its laboratories and shops to visitors for the first time in ten years. The occasion was the resumption of its Annual Open House.

The great strides made in the advancement of science and engineering since the last Open House was held a decade ago were reflected in the vast variety of exhibits and demonstrations. The deans and heads of departments were available to advise those who are interested in preparing for engineering and scientific careers.

Among the many events scheduled was a lecture demonstration on "Seeing Atoms with X rays," given by the Department of Physics. Visitors to the Internal Combustion Laboratory witnessed a Ford V-8 engine operated by manufactured household gas as well as an engine "knock performance" test displayed by the Department of Mechanical Engineering. The latest concepts in experimental communications and electronics circuits were demonstrated by the Department of Electrical Engineering and advances in aeronautical engineering were exhibited in the aerodynamics laboratory wind tunnel; the tail-spin, wing flutter, and other aeronautical phenomena were shown.

National Electronics Conference. Authors of papers to be presented at the 1951 National Electronics Conference should submit titles and 200-word abstracts to Dr. J. D. Ryder, Chairman of the program committee, not later than May 15, 1951. Titles and abstracts should be sent to Doctor Ryder at the Electrical Engineering Department, University of Illinois, Urbana, Ill.

Electrically Operated Pump Increases Phoenix Water Supply

A daily increase of 20,000,000 gallons of water has been made possible through the use of an electrically driven booster pump at Phoenix, Ariz. A booster station uses an 800-horsepower motor made by the General Electric Company to drive the pump. A 5-horsepower motor operates a valve which connects the pump to a 48-inch main.

Cost of the city's installation is about $70,000—a fraction of the estimated $400,000 cost of a new pipe line with the same capacity.

Because of the large increase in the number of water customers during the past year, the booster station was needed to step up the city's daily capacity of water lines from the Phoenix supply source on Verde River. The total number of Phoenix water customers has jumped more than 11,000 in the past year.

The pump has a peak capacity of 50,000 gallons per minute, or 72,000,000 gallons per day. The pipe line's capacity could be increased only by 20,000,000 gallons per day.

Engineers Joint Council Meeting Held on March 16

The Engineers Joint Council (EJC) held its regular meeting in the Engineering Societies Building, New York, N. Y., on March 16, 1951. James E. Todd, Chairman, presided.

The Executive Committee reported that T. E. Purcell had been asked to head a committee to follow legislation relating to air pollution and to appoint other engineers to serve with him. It had also asked E. S. Lee to make a study of possible EJC interest in patent protection and to report to the committee.

For the Engineering Man Power Commission, E. G. Bailey, temporary Chairman, presented a progress report. He announced the imminent selection of a chairman and an executive secretary. (At a meeting of the Commission on March 27, 1951, C. H. Brown took over the chairmanship and T. A. Marshall, Jr., the executive secretaryship.) A communication on the need for engineers is under preparation and will be sent to about 25,000 high-school principals, and to an equal number of teachers of science and mathematics.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Correction on Whitehead Digest

To the Editor:

I am sorry to note a serious error in the printing of the digest of my recent paper, "Stresses in Impregnated Paper Insulation," which appeared on page 297 of the April 1951 issue of *Electrical Engineering*. The illustration and caption used for Figure 2 are incorrect.

J. B. WHITEHEAD

(The Johns Hopkins University, Baltimore, Md.)

(*Editor's Note:* The correct Figure 2 with its caption are reproduced on this page.)

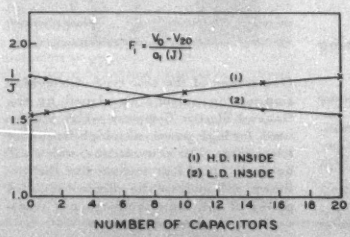


Figure 2. Graded cable. Variation of maximum oil stress with relative radial depths of a dense and of a less dense paper

Determining Phase Sequence

To the Editor:

It is frequently desired to establish the phase sequence and proper terminal markings of 3-phase lines, motors, and generators. From checking a number of textbooks and handbooks dealing with this problem, I arrive at the conclusion that the following fact is not generally known. The ordinary 2-wattmeter method of measuring power yields

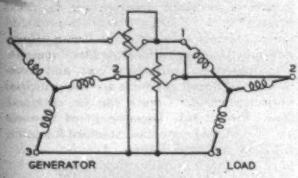


Figure 1. Schematic diagram for determining phase sequence

automatically the desired answer. The only prerequisite is a reasonably balanced load not at unity power factor. Every 3-phase induction motor fulfills this requirement, regardless of the load condition under which it may be operating.

As shown in Figure 1, denote with "3" the line which is common to the potential coils of the wattmeters and take both readings. Assign "1" to the line which yields the larger reading and "2" to the line with the smaller reading, measuring a load with lagging power factor. This gives the phase sequence 1-2-3.

With reference to Figures 1 and 2, the two wattmeter readings are, in general

$$P_I = E_{31} I_1 \cos(\theta_1 - 30°) \quad (1)$$

$$P_{II} = E_{32} I_2 \cos(\theta_1 + 30°) \quad (2)$$

In the case of a balanced load, all values with subscripts equal each other, so that we obtain

$$P_I = EI \cos(\theta - 30°) \quad (1A)$$

$$P_{II} = EI \cos(\theta + 30°) \quad (2A)$$

However, the term $\cos(\theta - 30°)$ is always associated with the current of the phase which leads the other. We see that $\cos(\theta - 30°) > \cos(\theta + 30°)$ in the range of lagging power factor $90° > \theta > 0°$.

In many applications the line common to

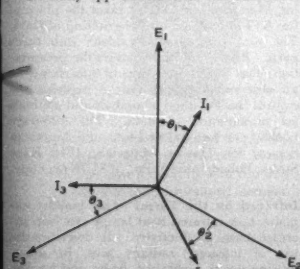


Figure 2. Vector diagram of voltages and currents

the potential coils of the two wattmeters may not be denoted by "3" but from the equations a general rule can readily be set down.

Rule: For an inductive load the larger reading of the 2-wattmeter method belongs to the line number in the cyclical sequence 1-2-3 following the arbitrarily assigned line number common to the potential coils of the two wattmeters for the correct electrical phase sequence; for a capacitative load, the larger reading belongs to the line number preceding the line number common to the potential coils.

Tabulating the assigned line numbers under this rule for correct electrical sequences gives:

	Assign to Larger Reading	
	Inductive Load	Capacitive Load
Common Line	Line Number	Line Number
1	2	3
2	3	1
3	1	2

This rule has many applications, that is, it enables one to determine if a synchronous motor operates underexcited or overexcited if the phase sequence of the line is known. If the larger reading is measured in line 1 (line "3" common potential line), the motor is underexcited and vice versa.

MICHAEL A. TSCHUPP

(291 Devoe Street, Brooklyn 6, N. Y.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

INDUSTRIAL AND SAFETY PROBLEMS OF NUCLEAR TECHNOLOGY. Edited by M. H. Shamos and S. G. Roth. Harper and Brothers, New York, N. Y., 1950. 368 pages, illustrations, diagrams, charts, tables, 8¼ by 5½ inches, linen, $4.00. Based on papers presented at a recent conference held at New York University, this book is devoted to the problems of the use of atomic energy. Part I considers details of the organization and operation of the United States Atomic Energy Commission. The fundamentals of nuclear physics, nuclear apparatus, the radiochemical laboratory, and industrial applications of radioactive isotopes are discussed in Parts II and III. Part IV deals with possible health hazards associated with the use of radioactive materials.

INGENIOUS MECHANISMS FOR DESIGNERS AND INVENTORS, Volume III. Edited by H. L. Horton. Industrial Press, New York, N. Y., 1951. 536 pages, diagrams, 9¾ by 6 inches, fabrikoid, $6.00. A companion to Volumes I and II of this series, this self-contained reference work is a part of a set which forms a comprehensive encyclopedia of mechanical movements. It contains illustrated descriptions of a large variety of standard and special mechanisms for use in designing automatic machines and other mechanical devices. Mechanisms of the same general type are grouped in chapters as in the previous volume.

INSTITUTE OF PETROLEUM ELECTRICAL CODE, Part I. Published by Institute of Petroleum, Manson House, 26 Portland Place, London, W. 1, England, 1950. 99 pages, tables, 9¼ by 7 inches, fabrikoid, ring binder, 9¼ by 7 inches, 26s. Prepared by a committee of experts, this loose-leaf compilation is the first part of a model code of safe practice for the petroleum industry. It carefully defines the circumstances in which special precautions should be taken, assesses and classifies the risks incident to various grades of petroleum and similar products, and develops effective methods of protection. The effects of static electricity are considered. The code ends with a series of rules of good practice.

INTRODUCTION TO MECHANICAL DESIGN. By T. B. Jefferson and W. J. Brooking. Ronald Press Company, New York, N. Y., 1951. 612 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $6.50. This textbook approaches the subject as a whole in the light of the functional purposes of a machine, its configuration requirements, economic considerations, the use of rational and empirical design data, and desired final appearance. Against this background is presented the elementary theory of machine elements, including a number of design considerations not usually covered in machine design texts. Although courses in the mechanics of materials and in the calculus are desirable prerequisites, they are not necessities.

LINES, NETWORKS AND FILTERS. By W. M. Breazeale and L. R. Quarles. International Textbook Company, Scranton, Pa., 1951. 293 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $6.50. Intended for use by third-year students who have finished a first course in a-c circuits and two years of college mathematics, this book is principally concerned with wire communication circuits. The first five chapters discuss in detail the general steady-state transmission-line relations. The next two are devoted to telephone lines and to ultrahigh-frequency and microwave line theory and practice. The theory of the exponentially tapered line is developed in the next chapter, and the last four chapters contain material on filters, matching networks, and equalizing networks. The rationalized meter-kilogram-second units are used throughout.

MATHEMATICAL ENGINEERING ANALYSIS. By R. Oldenburger. Macmillan Company, New York, N. Y., 1950. 426 pages, illustrations, diagrams, charts, tables, 9¼ by 6¼ inches, cloth, $6.00. Intended for use as a text in courses on engineering analysis and industrial physics, this book is written to aid those who need to express physical situations in the form of equivalent mathematical relations. It develops the basic laws of engineering from a minimum number of assumptions so that the reader can obtain a logical physical and mathematical picture of the fundamental concepts of engineering in common use. With this as a background, the various techniques for making simplifying assumptions in treating physical problems then are illustrated. A knowledge of advanced calculus, especially those aspects concerned with line, surface, and volume integrals, is assumed.

MOTION AND TIME STUDY, PRINCIPLES AND PRACTICE. By M. E. Mundel. Prentice-Hall, New York, N. Y., 1950. 457 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $4.65. This book is intended to provide a systematic, practical, and scientifically correct treatment of present-day motion and time study. It considers the development and application of the basic principles of successful work. Illustrative examples from a wide variety of industries and types of work demonstrate the highly important reasoning process involved in the application of procedures. Graphic analyses are presented in the form in which they would normally appear in practice so as to provide a working guide.

N. F. P. A. INSPECTION MANUAL. Edited by H. Bond. National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass., 1950. 330 pages, illustrations, diagrams, tables, 6¾ by 4¼ inches, fabrikoid, $3.00. This pocket book covers the inspection work done for fire protection and prevention by property owners, fire departments, and inspection departments of various agencies. Replacing the book "Field Practice," this volume contains additional material on special hazards, building construction, and life safety.

ORDINARY NON-LINEAR DIFFERENTIAL EQUATIONS IN ENGINEERING AND PHYSICAL SCIENCES. By N. W. McLachlan. Oxford University Press, New York, N. Y.; Clarendon Press, Oxford, England, 1950. 201 pages, diagrams, charts, tables, 9½ by 6 inches, cloth, $4.25. This book shows how certain types of nonlinear problems may be solved, and how experimental results may be interpreted by nonlinear analysis. It is chiefly confined to the presentation of various analytical methods employed in

the solution of important technical problems. A wide variety of these is included, and practical details are given. References are given to sources of more rigorous theoretical treatments of the methods used.

QUANTUM MECHANICS. By A. Landé. Pitman Publishing Corporation, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 307 pages, diagrams, charts, tables, 9¼ by 6 inches, linen, $5.50. This book serves as an introduction to the subject and emphasizes the physical background of quantum mechanics and its close relation to classical experience. The principles of quantum mechanics are derived from a critical analysis of a few standard experiments. In a similar inductive manner, the technique of matrix mechanics is developed. Considerable space is devoted to nonconservative processes, and the Dirac electron and the elementary theory of radiation are considered. The last chapter deals with mesons. A bibliography of standard works is included.

RADIATION MONITORING IN ATOMIC DEFENSE. By D. E. Gray and J. H. Martens. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1951. 122 pages, illustrations, diagrams, charts, 8 by 5½ inches, linen, $2.00. This practical working manual for radiological defense personnel provides full details on the use of all standard radiation detectors and the interpretation of their results. Brief background information is given on atomic energy, on radiation hazards, and on protective measures against atomic explosions. The book is intended for any one concerned with the measurement of radiation and requires no technical background to understand or use.

REFERENCE DATA FOR RADIO ENGINEERS. Third edition. Federal Telephone and Radio Corporation, an associate of International Telephone and Telegraph Corporation, New York, N. Y., 1949. 640 pages, diagrams, charts, tables, 8½ by 5½ inches, fabrikoid, $3.75. Designed to fill a gap between textbooks and handbooks, this manual is a comprehensive compilation of basic electrical, physical, and mathematical data frequently needed in the solution of engineering problems. The third edition includes material expected to be of value to the engineer-in-training as well as to those in the fields of research, development, production, and operation.

(THE) SOLUBILITY OF NONELECTROLYTES (American Chemical Society Monograph Series 17). By J. H. Hildebrand and R. L. Scott. Third edition. Reinhold Publishing Corporation, New York, N. Y., 1950. 488 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $10.00. In this third edition, the comprehensive survey of the theory of nonelectrolytes is completely rewritten and expanded to over 2½ times the size of the previous edition. New chapters deal with multicomponent systems, mixtures of gases, solid solutions, high polymer solutions, surface phenomena, and chemical equilibria and reaction rates. The treatment of metallic solutions is greatly extended. Still limited to a discussion of the equilibria involved in solubility, no consideration is given to rate processes in liquids and solutions.

SYMPOSIUM ON RAPID METHODS FOR THE IDENTIFICATION OF METALS (Special Technical Publication Number 98). American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 77 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $1.75. This symposium is a collection of methods and techniques of particular value in the field. The first three papers deal with the general principles of spot testing with chemical reagents, electro spot testing and electrographic analysis, and of modern instrumentation for the rapid identification of metals. The remaining six papers discuss specific applications of these methods or of combinations or modifications of them.

THEORY AND DESIGN OF INDUCTANCE COILS. By V. G. Welsby, with a foreword by W. G. Radley. Macdonald and Company, Ltd., 43 Ludgate Hill, London, E. C. 4, England, 1950. 180 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, 18s. Of primary interest to the circuit designer, this book assists him in the selection of suitable coil designs. It shows how the performance of "inductors" can be related to their shape and size and the materials of which they are made. The methods of designing various types of inductance coils are illustrated by numerous examples. A short bibliography is included.

TRANSFORMER ENGINEERING. By the late L. F. Blume and Associates. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 500 pages, diagrams, charts, tables, 9¼ by 6 inches, linen, $7.50. This book is written to help engineers solve the technical problems arising in the specification, selection, application, and operation of transformers. Emphasis is placed on presenting the essential physics concerned in each problem, rather than a complete or exact mathematical treatment. In this second edition, compiled 12 years after the first, the major changes occur in the chapters on insulation, thermal characteristics, and the load ratio control problem.

TV MASTER ANTENNA SYSTEMS (Installation and Distribution). By I. Kamen and R. H. Dorf. John F. Rider Publisher, 480 Canal Street, New York 13, N. Y., 1951. 356 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, $5.00. Designed as a working manual, this book discusses the installation and distribution, maintenance, usage, and merchandising of television master antenna systems. First individual-receiver antenna installations are considered. The largest part of the text is devoted to detailed expositions of important master antenna systems now in manufacture, complete with schematic diagrams, performance figures, and design data. The latter chapters deal with video distribution systems and general sales methods.

POWER SYSTEM STABILITY, Volume II. Power Circuit Breakers and Protective Relays. By E. W. Kimbark. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 288 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $8.00. This is the second volume of a 3-volume work intended for use by power-system engineers and by graduate students. The present volume covers power circuit breakers and protective relays, including material on rapid reclosure of circuit breakers and on the performance of protective relays during swings and out-of-step conditions. Both 3-pole and selective-pole tripping and reclosure are discussed. Numerous references and a set of problems are included at the end of each chapter.

PRINCIPLES OF ELECTRICAL ENGINEERING, THEORY AND PRACTICE. By G. C. Bialock. Third Edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 605 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $5.50. Serving as a textbook for nonelectrical engineering students, this book presents fundamental principles in concise form with frequent references to practical applications. In this third edition, the author has amplified and modernized the text. A new chapter on dielectric fields and circuits is added. The superposition, reciprocal, and Thévenin theorems are added to a later chapter, and the treatment of both d-c and a-c networks is expanded considerably. The chapter on electronics is enlarged and amplified both as to theory and practical applications.

REGELTECHNIK. By K. Seidl. Franz Deuticke, Vienna, Austria, 1950. 68 pages, diagrams, charts, tables, 9¼ by 6½ inches, paper, $1.70. This book explains the principles of various types of automatic control equipment as used in power stations; conveyor systems; automatic drives for cars, ships, and airplanes; the control of gas pressure and flow, and so forth. It covers the fundamentals and theory of control and regulating equipment, the characteristics of different types of control mechanisms and circuits, and the underlying mathematical principles.

TRAVELING WAVES ON TRANSMISSION SYSTEMS. By L. V. Bewley. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 543 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $12.00. This book is a collection of the modern theories of transient voltage phenomena on electric power transmission lines and in transformer windings. Special emphasis is placed on the use of these theories in the design of lightning-proof transmission lines. The present edition is enlarged by half to include new developments in the field and to include problems at the end of the chapters. A working knowledge of operational calculus is assumed.

VOLTAGE STABILIZERS. By F. A. Benson. Published by Electronic Engineering, 28 Essex Street, Strand, London, W. C. 2, England, 1950. 125 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, linen, 12s.6d. Based on a series of articles published in "Electronic Engineering," this monograph reviews methods of stabilizing voltages and contains much data which have been published only in the various scientific periodicals. Three main methods of stabilizing voltage, that is, magnetic saturation, glow-discharge tubes, and thermionic tubes, are discussed in detail in separate chapters.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Industrial Utilization of Fission Products—A Prospectus for Management. The Stanford Research Institute has made a study of the possible industrial uses that can be made of atomic by-products. The scope and objectives of the study program are described in detail in this booklet which was prepared under contract to the Atomic Energy Commission's Division of Reactor Development. The properties, availability, cost, and possible uses of fission products are the principal subjects covered. Copies can be obtained from: Project 361, Department of Business and Industrial Economics, Stanford Research Institute, Stanford, Calif.

American Standard for Brushes for Electrical Machines. The standard contains definitions, dimensions and tolerances, and test procedures needed for the manufacture and use of these brushes. Definitions are given for five types of brushes—carbon, carbon-graphite, electrographitic, graphite, and metal-graphite. Brushes also are classified and defined into three groups—fractional horsepower, industrial, and split brushes. Diagrams illustrating various types of brushes, their corners, ends, edges, and shoulders, are included. Shunt terminals for brushes to be used in reaction or box type holders are also illustrated in the standard. An appendix at the back contains a spring design data form sheet. Copies of this standard, *C64-1-1950*, may be obtained from the American Standards Association, 70 East 45 Street, New York 17, N. Y.

Safety Manual for the Die Casting Industry. Prepared by the American Die Casting Institute, this is a comprehensive coverage of all departments, operation, and procedures. An appendix contains blueprints of safety devices, typical record and report forms, and a complete list of safety organizations, text books, and periodicals. Illustrated. Copies are available from the American Die Casting Institute, Inc., 366 Madison Avenue, New York 17, N. Y., for $5.00 a copy.

Manual on Quality Control of Materials. Prepared by the American Society for Testing Materials (ASTM), it takes the place of the ASTM Manual on Presentation of Data. The new manual is organized into three parts. Part 1 essentially covers the presentation; Part 2 presents limits of uncertainty of an observed average; Part 3 explains the control chart method of analysis and methods for presentation of data. The 100-page booklet can be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at $1.75 per copy.

Infrared on the Farm. This booklet explains how infrared heat lamps can help increase farm productivity. It describes the use of infrared radiant heat in dehydrating meats, vegetables, fruits, and berries. For a copy write the Advertising and Sales Promotion Department, Westinghouse Lamp Division, Bloomfield, N. J.

New double-loop directional element

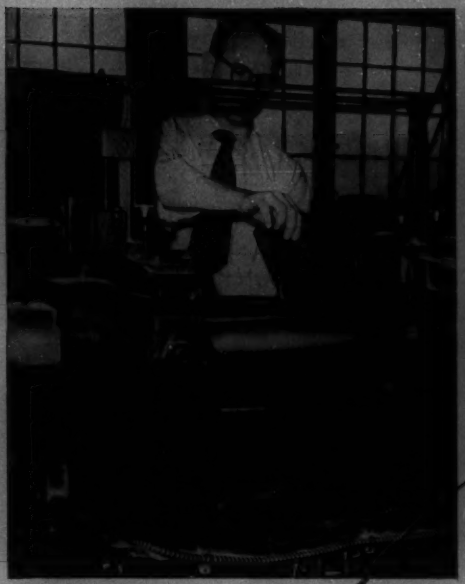
ELIMINATES VIBRATION...

The Type HZM, and Type HZ, high-speed impedance relays are now available with the new double-loop directional element.

Westinghouse High-Speed Impedance Relays now offer you extra operating benefits. A new directional element, featuring double-loop design, eliminates troublesome 120-cycle vibration.

The torque produced in each loop is a double frequency sine wave. However, as these waves are 180 degrees out of phase and offset in the same direction, the net torque in both loops is a constant value—eliminating vibration. The result is an efficient, high-speed directional element, providing low burden, good sensitivity in a sturdy rugged enclosure . . . a sharper intelligence for vital relaying applications.

For complete information write for Silent Sentinel Bulletin No. B-4794. Address: Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-40402



This rubber mill is installed for the exclusive use of our research department. Here, sample rubber compounds are milled under conditions that are identical with those encountered in actual production.

Here is the oxygen bomb—installed to provide accelerated aging test data. Results are available for all American Rubber Insulations that are tested in the oxygen bomb.

In this drop tester, the cable is operated under full load. The heavy steel weight is repeatedly dropped on the cable until it fails. At the top of the column is a counter that gives a numerical indication of how much such abuse the cable can withstand.

This Viscometer is one of the main tools for maintaining quality control *on the production line.* Rubber samples from every batch are carefully examined to make sure that they meet all specifications drawn up by the research department.

6 answers to your rubber insulation problems

1. AMARINE-40 — **UNDER GROUND OR UNDER WATER.** High voltage service for submarine power cables and for general use above 7500 volts.

2. AMERZONE — **OZONE-RESISTANT.** Plus resistance to heat and moisture.

3. AMARINE RWS — **HOT OR DAMP LOCATIONS.** Low water absorption, excellent heat resistance.

4. AMERITE — **GENERAL USE.** Performance grade compound. Use where copper temperature will not exceed 60°C.

5. AMPEROX — **HEAT-RESISTANT, GENERAL USE.** For copper temperatures up to 75°C., and voltages up to 7500.

6. AMERPRENE — **OIL, FLAME, SUNLIGHT AND AGE-RESISTANT.** Extra flexible jacket. High Neoprene content.

Close laboratory control assures you the best in material and design

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No matter what your problem—high voltage, temperature, oil, moisture, ozone or sunlight—there's a standard American Insulation to solve it.

For complete test data on any of these compounds, call your American Steel & Wire Company District Engineer or write to American Steel & Wire Company, Rockefeller Building, Cleveland 13, Ohio.

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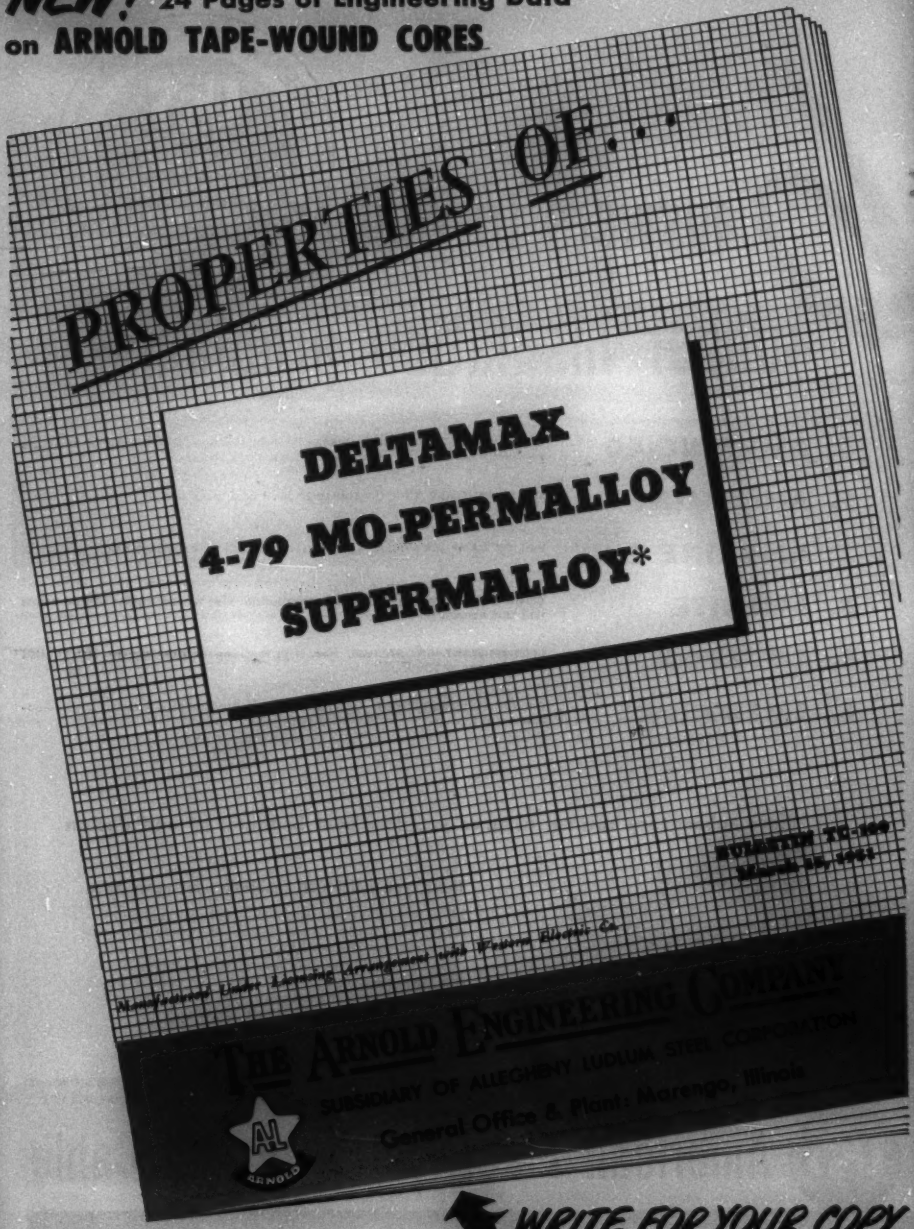
USS **American Electrical Wire and Cable**

UNITED STATES STEEL

NEW! 24 Pages of Engineering Data
on **ARNOLD TAPE-WOUND CORES**



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It's a fact that

- Some of the very low expansion AlSiMag Ceramics have excellent heat shock qualities and can be heated red hot and suddenly cooled without damage.

- AlSiMag Ceramics are ideal elastic bodies. They do not show any plastic deformation and retain their original shape after release from strain.

- AlSiMag Ceramic plates can be ground to a flatness of 1 or 2 light bands, and retain this flatness even if subjected to severe temperature changes. What could be better as a reference subject?

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AlSiMag

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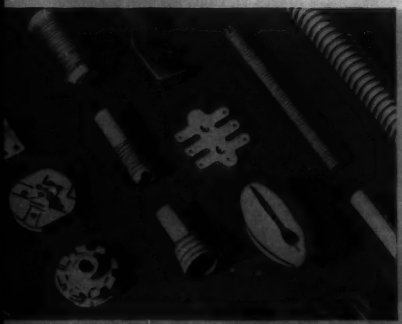

- Submit your difficult material requirements to American Lava Corporation and you will obtain free consultation for the best material for your application and helpful recommendations for solving your designing problems.

- It is this service which has given American Lava Corporation the reputation as THE consulting firm among ceramic manufacturers.

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INDUSTRIAL NOTES ....

A $2,800,000 Expansion Program is Launched by Carboloy. In order to meet a rapidly increasing demand for tungsten carbides, the Carboloy Company, Inc., a General Electric affiliate, has launched a $2,800,000 plant expansion program. Of the total, approximately $800,000 is being devoted to expanding the present Carboloy plants in Detroit, Mich., while $2,000,000 is for constructing and equipping a new plant in Edmore, Mich.

U. S. Steel Elects New Director. The United States Steel Corporation has announced the election of Herbert E. Smith as a Director of the corporation and a member of its Finance Committee, succeeding the late Robert C. Stanley.

Ohio Brass Appointments. The Ohio Brass Company has appointed Joseph B. Doran and William E. Morrison district managers in the Eastern territory, with headquarters in New York City.

Sylvania Purchases Continental Can Building; Appointments. Sylvania Electric Products, Inc., has purchased the Continental Can Company building in Wheeling, W. Va., where it will manufacture fluorescent lighting fixtures. The company has also announced the appointments of D. W. Gunn as equipment sales manager, and G. V. Bureau as government sales manager.

Alcoa Appointment. Lewis P. Favorite has been named manager of the Aluminum Company of America's New York district sales office.

Uptegraff Manufacturing Appoints Pittsburgh District Manager. R. E. Uptegraff Manufacturing Company has announced the appointment of H. W. Petty as manager of the company's newly opened Pittsburgh sales office.

Lear Elects Vice-President. Albert G. Handschumacher has been elected a Vice-President of Lear, Inc. Mr. Handschumacher will assume the responsibilities of assistant general manager of the company and relinquish his post as assistant to the president.

Westinghouse News. The Westinghouse Electric Corporation has purchased land in Farmers Branch, Tex., for construction of a light-bulb warehouse. Completion is scheduled for the summer of 1951. The corporation also has announced plans for construction of a headquarters plant and engineering laboratories for their new electronic tube division in Elmira, N. Y. The plant will produce electronic tubes for the military services and for defense industries.

Westinghouse also has announced the appointment of E. D. Delano as manager of the New England district, with headquarters in Boston, Mass., succeeding L. E. Lynde, newly elected Vice-President, who will have charge of the company's government activities in Washington. Other appointments are: Dr. Rolland M. Zabel, manager of engineering, Westinghouse lamp division; Dr. S. W. Herwald, manager, engineering development division; P. L. Fosburg, manager, design section; N. V. Petrou, manager, computing devices section; R. E. Span, manager, analytical section; C. E. Bagwell, manager, autopilot section; G. F. Towner, manager, turret systems section; H. D. Lawton, supervisory engineer in charge of design work on fixed gunfire control systems; Harry D. Hanafus, purchasing agent, electronic tube division; Harry F. Blythe manager of accounting, tube division W. H. Dickinson, director, manufacturing division, Engineering Department; G. P. Longabaugh, director, headquarters manufacturing division, Equipment Department; and George S. Evans, manager, commercial engineering, Lamp Department.

Allis-Chalmers Appointments. Gerald E. Smart has been named plant engineer, assisting J. J. De Windt, general superintendent of maintenance, time study, and tool design, at the Allis-Chalmers Manufacturing Company's Norwood (Ohio) works. Dwight H. Lory has been appointed to the Electrical Sales and Engineering Department at the Norwood works. Allis-Chalmers has also announced the appointments of nine new sales representatives; those named and the district offices to which they have been assigned are: John W. Becker, Syracuse; Joseph L. Luber, Washington, D. C.; Joseph M. Duncan, Atlanta; Charles C. Leach, Philadelphia; Floyd Blackwell, Jr., Chattanooga; David C. Emery, Cleveland; William V. Glasser, Omaha; James R. McCausland, St. Louis; and John Rayburn, Amarillo.

Marcus Transformer Appoints New Sales Representative. W. D. Evan, Jr., Pacific Industries, 1045 South Olive Street, Los Angeles 15, Calif., has been appointed sales representative for the Marcus Transformer Company of Hillside, N. J. Mr. Evan succeeds Robert Young and Company.

RCA Victor Names Seven Product Managers. The RCA Victor Division of the Radio Corporation of America has announced the appointment of seven product managers in the company's newly organized product administration division. The new product managers are: E. E. Minett, research product section; A. C. Lindquist, communications product section; M. A. Trainer, broadcast product section; R. A. Teare, theater, visual, and sound products section; M. S. Klinedinst, industrial product section; H. W. Hucke, product coordination section; and R. H. Holmes, contract administration section.

(*Continued on page 22A*)

use one of these 6 Reduced Voltage Starters

To prevent damage to many machines or to materials in process, squirrel cage motors often need gradual acceleration. For such applications, one of these reduced voltage starters will provide the desired speed-torque control.

This line of A-B starters is extremely versatile, providing either manual or automatic starting . . . with 2 or 3 step acceleration . . . or stepless control up to full speed . . . to fit the most critical motor starting requirement.

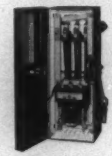
MANUAL—TRANSFORMER TYPE

Manual transformer type starter up to 125 hp, 220 v; 250 hp, 600 v max. Air break or oil immersed contacts. Automatic reset overload relays. Time delay mechanism determines proper time interval for manual switch-over of hand lever.

BULLETIN 646

MANUAL—COMPRESSION TYPE

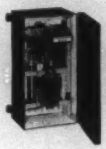
Manual compression resistance starter up to 50 hp, 220-600 v max. Graphite discs in the insulated tubes are compressed with the hand lever for stepless speed control. Ideal starters for chain or belt drives. Overload relay protection.



BULLETIN 640

AUTOMATIC—3 STEP RESISTANCE

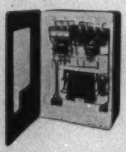
Automatic resistance starter up to 400 hp, 220-600 v max. Accelerates squirrel cage motors in 3 steps. Resistors easily adjusted for ideal starting of motors on power networks. For more than 3-point control, use Bulletin 742 starter, below.



BULLETIN 741

AUTOMATIC—TRANSFORMER TYPE

Automatic reduced voltage starter up to 300 hp, 600 v max. An accurate timing relay controls the accelerating time. Operator touches start button—the starter does the rest. Available in standard, watertight, and dust-tight enclosures.



BULLETIN 746

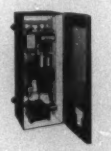
AUTOMATIC—2 STEP COMPRESSION

Automatic resistance starter with preset adjustable graphite resistors up to 250 hp, 220-600 v max. Push button closes starting circuit through resistors. Later, timing relay closes running contactor and cuts out the starting resistors.

BULLETIN 740

AUTOMATIC—STEPLESS TYPE

Fully automatic resistance starter with solenoid controlled graphite disc resistors rated up to 500 hp, 220-600 v max. Stepless control of current and speed. Acceleration adjustable to avoid lamp flicker. Overload relay protection.



BULLETIN 742

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A-B Quality

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REDUCED VOLTAGE STARTERS

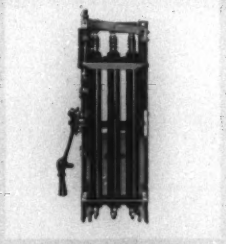
QUALITY

351-MR

for VELVET SMOOTH ACCELERATION

use these Allen-Bradley Starters with Graphite Compression Resistors

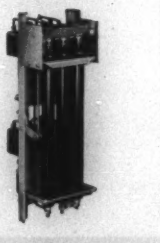
With these Allen-Bradley compression resistance starters you can start squirrel cage motors with such velvet smoothness that there is no voltage dip . . . no lamp flicker. The secret of this stepless acceleration lies in the smooth control of the Allen-Bradley graphite compression resistors which are shown below.



BULLETIN 640 MANUAL
Stepless Resistance Starter

The motor current passes through the graphite disc resistors. Compressing them with the hand lever reduces the starting resistance steplessly until it is shunted automatically by the running contactor.

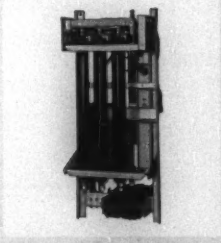
Bulletin 640 manual starters have a hand lever for manually compressing the resistors. At maximum speed position, a magnetic contactor automatically connects the motor to full voltage.



BULLETINS 740 & 741 AUTOMATIC
2 and 3 Step Resistance Starters

In these two resistance starters the adjustable resistors are arranged in 2 or 3 steps. Each step is cut out, successively, by timing relays. These starters can be easily adjusted for equal current inrush per step.

Bulletin 740-741 starters are rugged, automatic starters.



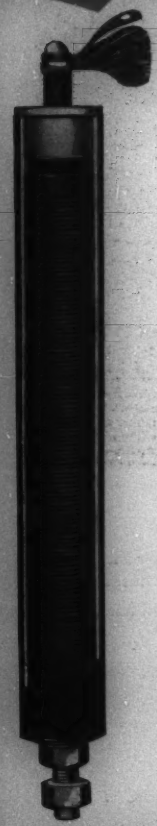
BULLETIN 742 AUTOMATIC
Stepless Resistance Starter

In this starter, compression of the graphite discs is done automatically by a solenoid mechanism. Absolutely velvet smooth acceleration is obtained. No other starters provide similar stepless control.

Bulletin 742 resistance starters prevent lamp flicker on network systems. They provide automatic stepless starting for machines and processes which are easily damaged by sudden starting.

BULLETIN 646 TRANSFORMER TYPE STARTER

For loads with high starting friction, requiring sudden applications of power, use the Bulletin 646 manual or the Bulletin 746 automatic transformer type starters.



Cutaway view of Allen-Bradley graphite resistor tube showing discs, insulating lining, and the pressure terminal.

Write for Bulletins to Allen-Bradley Co., 1316 South Second Street, Milwaukee 4, Wisconsin

ALLEN-BRADLEY
REDUCED VOLTAGE STARTERS
QUALITY

A-B Quality

351-MR

High among the advantages of Stackpole Silver Tungsten Contacts is the fact that they stand up well under corrosive atmospheric conditions. Salt air, high humidity, sulfide atmospheres and similar adverse conditions do not affect this material to the extent that they do many other refractory contact materials.

Probably no other contact material does a better job of assuring low contact resistance in continued operation where heavy arcing is present or under closed conditions. Stackpole silver tungsten contacts are made in practically any desired shape or size and in grades specifically "tailored" to your application.

HANDY CONTACT DATA

Stackpole booklet No. 12 contains a wealth of data to help solve your contact problems. Write for your copy today.

STACKPOLE CARBON COMPANY
ST. MARYS, PA.

ELECTRICAL BRUSHES (All carbon, graphite, metal and composition types) • RARE METAL CONTACTS WELDING RODS, ELECTRODES and PLATES • BRAZING BLOCKS • RHEOSTAT PLATES and DISCS PACKING, PISTON and SEAL RINGS • CARBON REGULATOR DISCS • SINTERED IRON COMPONENTS and many other items.

SORGEL AIR-COOLED TRANSFORMERS

Dry-Type

for Every Purpose

¼ to 1000 Kv-a. Single phase
1 Kv-a. to 2000 Kv-a. 3-phase

To operate 115 volt lighting and portable equipment from 230, 460 or 575 volt power circuits.

To operate special equipment from standard circuits.

To change odd voltages to standard voltages, and phase changing.

For indoor installations without fire-proof vaults

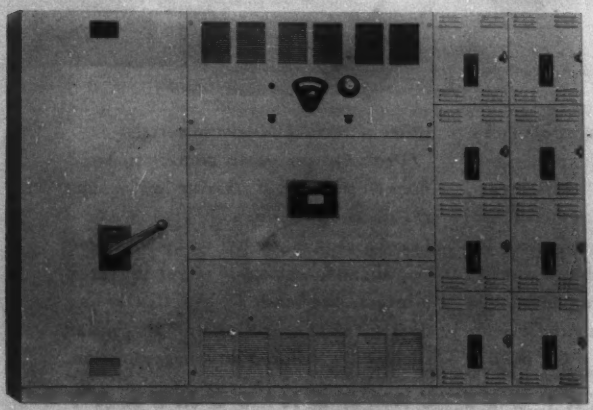
¼ Kv-a. Single Phase 460/230 to 230/115 volt

15 Kv-a. 3-phase Wall mounting type. Showing connection compartment with solderless terminals

Unit Sub-Stations

For interior high voltage distribution systems with transformers at load centers.

Sizes up to 2000 Kv-a. and up to 15,000 volts.



2000 Kv-a. 12,000 volt sub-station, with primary fused load interrupter switch, temperature indicator and alarm, and extra contacts that may be used to operate forced draft fans to increase capacity 25%

Sales Engineers in Principal Cities

Sorgel Electric Co., 846 W. National Ave., Milwaukee 4, Wis.

Pioneers in the Development and Manufacturing of Air-Cooled Transformers

(*Continued from page 18A*)

Hinck Heads Du Mont Component Sales. Edwin B. Hinck has been made sales manager of the electronic parts division, Allen B. Du Mont Laboratories, Inc. Mr. Hinck succeeds Harry Van Rensselaer, who has been recalled by the United States Air Force.

G-E News. The General Electric Company has appointed L. T. Callahan manager of operations of their aircraft gas turbine divisions; W. G. Arnold, manager of manufacturing, Welding Department; G. P. Foster, district representative for 2-way communications equipment, commercial equipment division; and Robert R. Person, staff assistant to the manager of manufacturing, large apparatus division, and secretary of the division's appropriation committee.

NEW PRODUCTS • •

Leak Detector. Operating on the principle that the tendency of hot platinum to emit positive ions is stimulated enormously by infinitesimal traces of halogens or their compounds, a new and extremely sensitive leak detector for use in vacuum systems down to a pressure of one micron of mercury has been announced by Distillation Products Industries, Division of Eastman Kodak Company. In operation, the glass sensitive tube of the leak detector, model *LD-01*, is sealed into the system under test and the system then is pumped down to a moderate vacuum. A jet of harmless Freon gas, or other halogen-contained gas (in small cylinders), then is directed against portions of the system suspected of leaking. When the jet strikes a leak there is a sudden deflection of the meter needle on the instrument face because the gas—entering the system—instantly increases the ability of a hot platinum anode in the sensitive tube to emit positive ions. Further information on the detector may be obtained from Distillation Products Industries, Rochester, N. Y.

Mechanical Failures Forecast by Coating Process. A testing process which can forecast weeks and months in advance where failure will occur in an airplane engine or other mechanical products has been developed by the Magnaflux Corporation, 25 West 43rd Street, New York 18, N. Y. The test involves the use of an extremely brittle material known as Stresscoat which is sprayed on the part to be tested. When the test part is subjected to the same kind of load it will undergo in service, the metal deforms or stretches slightly in an amount proportional to the load. The brittle coating, however, will not stretch, and cracks like glass at the points where the strains are heaviest. The coating can be made to crack when the metal beneath it is deformed as little as 0.0001 inch per inch of length. Metal parts fail from fatigue in

(*Continued on page 28A*)

REASONS WHY POWER MEN PREFER
VICTOR SUSPENSION INSULATORS

V CONTROLLED FORMING plus smooth, hard glaze give unsurpassed self-cleaning characteristics. Maintenance costs are reduced, especially in contaminated areas.

V ALL METAL PARTS are hot-dipped galvanized to assure maximum resistance to weathering and corrosion.

V SPECIAL "CUSHION" COATINGS at all joining surfaces eliminate problems caused by thermal variations and mechanical shock.

V CONTROLLED TESTING and PROCESSING of cement provide high bond strength at all assembly joints.

V HEAVY OUTER EDGE of porcelain provides added resistance to chipping.

V RUGGED, THICK CORRUGATIONS and smooth, rounded edges give maximum resistance to mechanical impact.

VICTOR NO. 900 SUSPENSION INSULATOR
For complete engineering data on this and other sizes and types of suspension units, write today for Bulletin No. 4.

Features like these are just an indication of the vast amount of research and engineering which go into the design and manufacture of VICTOR Suspension Insulators. No wonder power men prefer VICTOR Suspension Units.

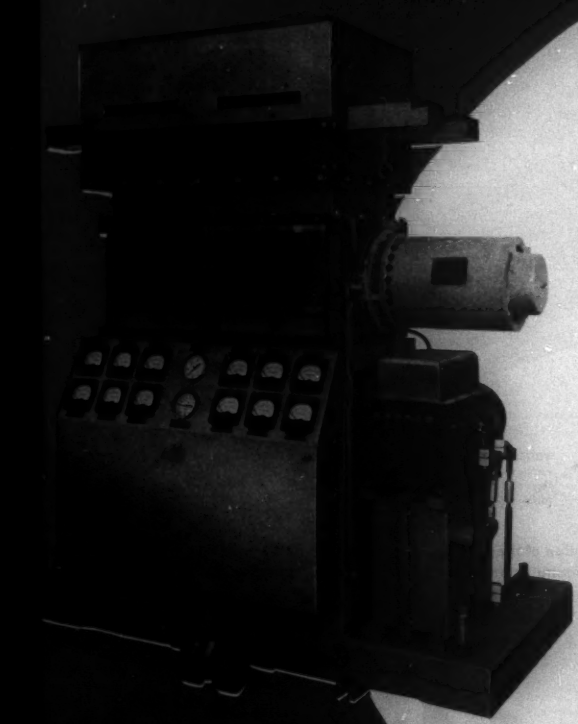
Do You Know that...

Every porcelain insulator produced at VICTOR is subjected to the most rigid controls throughout its entire manufacture . . . from laboratory tests on every lot of raw materials to routine high frequency and 60 cycle flashover with modern testing equipment? Result—VICTOR insulators more than meet industry standards.

Specify
VICTOR
SUSPENSION INSULATORS

VICTOR INSULATORS, INC. VICTOR, N. Y.

SEVEN I-T-E MECHANICAL RECTIFIERS



Two years ago, Buffalo Electro-Chemical Company, Inc., Buffalo, N. Y., installed two I-T-E Mechanical Rectifiers, the first mechanical rectification units ever built in this country.

This pioneering spirit of Buffalo Electro-Chemical's progressive management justified itself to the extent that at present I-T-E has orders for five more Mechanical Rectifiers—to augment Buffalo's current modernization program.

I-T-E's Mechanical Rectifier has benefited Buffalo Electro-Chemical—and can handle your low voltage power conversion requirements more effectively.

1 **HIGHER EFFICIENCY**—actually 96% or more in the 100 to 400 volt range, because silver to silver contact minimizes voltage drop in rectifying element.

2 **SPACE SAVINGS** — extremely compact grouping of all operating and protective apparatus.

3 **EASY, LOW-COST INSTALLATION**—unit assembly at factory allows "packaged" delivery, easy installation. No special structural foundations are required; no crane service is needed in rectifier room.

4 **SIMPLE, LOW-COST MAINTENANCE**—maintenance is almost entirely mechanical, requiring no trained personnel, complicated tools or instruments for servicing.

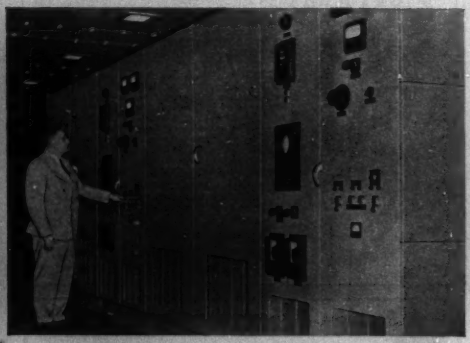
5 **SIMPLE OPERATION**—push-button starting without preliminary warm-up of any kind; immediate connection to load.

6 **SAFETY**—use of low voltage in your cell room increases safety to operating personnel and equipment.

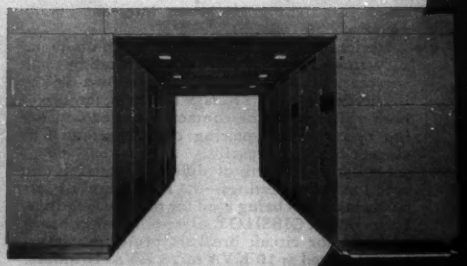
FOR BUFFALO ELECTRO-CHEMICAL

TYPICAL I-T-E MECHANICAL RECTIFIER ARRANGEMENTS

Factory assembly of two 10,000 ampere units with outdoor transformer (only one of two shown), throat connection through wall rectifier enclosure, operating aisle and d-c switchgear compartments.



Close-up of control and instrument panel. The thoroughness of I-T-E engineering is illustrated by the overhead lights, furnished with the installation and assuring proper illumination of the control panel.



View looking through operating aisle and control panel to left, d-c switch connecting d-c bus overhead.

I-T-E

MECHANICAL

I-T-E Circuit Breaker Company

Power Switch

Canadian Mfg. & Sales:

R&IE

MECHANICAL RECTIFIER

Let Gibson engineers help you make *Efficient* use of CRITICAL MATERIALS in Electrical Contacts

GIBSILOY silver-tungsten contacts used in circuit breakers; Left, for 15 to 30 amps. rating; right for 40 to 50 amps. rating.

Efficient use of critical materials in contacts involves (1) the determination of the best size and design, and (2) the selection of the right material for the function to be performed.

Extremely small amounts of contact materials often perform big jobs. In small circuit breakers, contacts weighing less than ½ gram are capable of interrupting 5000 amps. at 125 volts, and contacts weighing 2½ grams interrupt 10,000 amps, at 600 volts.

Devices otherwise similar in design often employ contacts of different sizes depending upon current and voltage ratings, as shown in the illustration. On high voltage breakers, the size of both main and arcing contacts is varied depending upon KVA rupturing capacity as well as current carrying capacity.

Similarly, contacts of different materials are used for various ratings—the less critical or less costly materials being used for the lower ratings. For example, GIBSILOY silver-tungsten contacts are used for circuit breakers protecting transformers rated at 10 KVA to 25 KVA. In similar circuit breakers for transformers rated at 3 KVA and 5 KVA, contacts of the same size are used but are made of GIBSILOY silver-nickel for the moving contacts and GIBSILOY silver-graphite for the stationary contacts, thus conserving critical tungsten.

Consult Gibson engineers regarding your designs or write for contact application questionnaire.

Serving Industry with Quality Electrical Contacts and Contact Assemblies.

Gibsiloy — Manufactured by GIBSON ELECTRIC COMPANY
8348 Frankstown Ave., Pittsburgh 21, Pa.

Representatives in Boston, Chicago, Detroit, New York, Rochester (N. Y.), Los Angeles, San Francisco, Seattle.

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Experiments and Lecture Demonstrations

Designed by Vickers to help students obtain a wider knowledge of the characteristics and applications of high-performance self-saturating magnetic amplifiers.

- Permits study of all three basic single phase self-saturating circuits.
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SIGNAL SYSTEMS TO YOUR SPECIFICATIONS OR STANDARDIZED DESIGNS TO COVER MANY DIFFERENT TYPES OF SERVICE. Consider for example our type MLBR-200 as illustrated; when the supervized contacts become abnormal the audible signal is sounded and the engraved message is lighted in red and white. Toggle operation cuts off audible and lights message in red. When contacts restore to normal, the audible is again sounded automatically and the message is lighted in white. Toggle operation removes the audible signal, and lamps.

ILLUMINATED MESSAGE AREA 2" W. x 1" H. Individual boxes molded of bakelite, (3⅛" x 1½"), with PLUG-IN relay in rear. Systems for voltages to 250 V. AC or DC. Attractive prices.

Established 1930

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MORRISTOWN, N. J.

BIBLIOGRAPHY on ELECTRONIC POWER CONVERTERS

A compilation of considerable reference data on power rectifiers and inverters, published in chronological sequence beginning with 1903. Items are arranged alphabetically by the author's surname, and are further classified according to text matter. Prepared by the Subcommittee on Papers and Speakers of the AIEE Electronic Power Converter Committee.

Priced at $1.00 ($0.50 to AIEE members), S-35 (February 1950) is available from the Order Department, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 39th Street, New York 18, N. Y. 5-51

The ADVANCED DESIGN FEATURES of the

KEARNEY Type "T" TRIP-OUT

200 AMPERE

Assures You of

Better Protection

of Equipment on Lines
Up to 15,000 Volts

Here's why—

- Silver to silver contacts for heavy loads
- High conductivity copper current path through switch
- Floating top contact to assure proper contact alignment
- Fuse cartridge opens at both ends—assures rapid expulsion of arcing gases and high interrupting capacity
- Wide cartridge hinge assure proper contact engagement when switch is closed

For complete detailed information including prices, write today.

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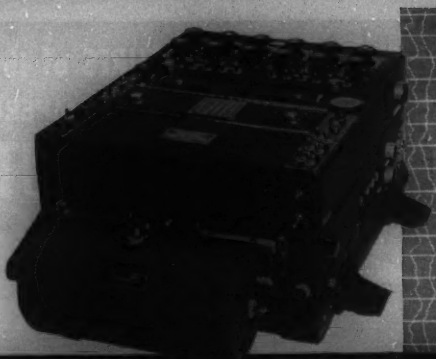
BETTER CONSTRUCTION *Safer* MAINTENANCE



the *NEW* S-8 Oscillograph

Here, in a versatile instrument of advanced design, are all the things you need for complete oscillographic recording. The Hathaway Type S-8 Oscillograph, which has long been the standard of oscillographic recording, has been improved to meet the rapidly expanding demands of modern research. Whether your measurement problems are simple or complex, the NEW Type S-8 Oscillograph has the inherent capabilities necessary to measure vibration, pressure, acceleration, and strain with new ease and accuracy.

The newest features include:

QUICK-CHANGE TRANSMISSION *fully enclosed with gears running in oil* **to provide instantaneous selection of 16 record speeds over the range of 120:1**

CHART TRAVEL INDICATOR provides continuous indication of chart motion. Operator knows instantly by flashing lamp if anything should happen to interfere with chart motion

FULL-RESILIENT MOUNTING FOR MOTOR AND TRANSMISSION isolates all possible vibration and makes possible the use of modern super-sensitive galvanometers

NEW GALVANOMETER STAGE accommodates all Hathaway galvanometer for recording milliamperes, microamperes, or watts

NEW RECORD-LENGTH CONTROL AND NUMBERING SYSTEM designed for long, trouble-free service under all kinds of ambient conditions

All the other valuable features are retained, such as

PRECISION TUNING-FORK-CONTROLLED TIMING SYSTEM produces either 1/10-second or 1/100-second time lines across sheet

WIDE RANGE OF GALVANOMETER TYPES AND CHARACTERISTICS provide for almost any recording requirements. Natural frequencies to 10,000 cps. Sensitivities to 50,000 mm per ma, single and polyphase watts

DAYLIGHT LOADING AND UNLOADING RECORDS TO 200 FT. IN LENGTH, width to 10 inches

SIMULTANEOUS VIEWING AND RECORDING

AUTOMATIC BRILLIANCY CONTROL

12 TO 92 ELEMENTS

Whatever your needs may be, investigate the NEW Type S-8 Oscillograph and its 170 types of galvanometers — the most versatile equipment in existence for general-purpose applications.

WRITE FOR BULLETIN 28-1-J

Hathaway
INSTRUMENT COMPANY
1315 SO. CLARKSON STREET • DENVER 10, COLORADO

(*Continued from page 22A*)

service after being subjected to the same load millions of times. Stresscoat fails the first time the load is applied, in the same place where the part will eventually fail in service. At present the coating is being used in testing of aircraft engine connecting rods, wings and structural parts, and critical components of different mechanical products. Further information on this coating is available from the Magnaflux Corporation.

Resistance Thermometer. Designed to overcome problems faced in making correct temperature readings of stored petroleum products, the Weston model *918* averaging resistance thermometer can be installed for use in existing tanks without taking the tank out of service. Accurate average temperature readings to within one-half degree Fahrenheit can be made regardless of the product, product level, and temperature gradient of the product in the tank. Readings can be obtained in a few seconds as compared to the long necessary immersion time for cup case thermometers. The Weston model *918* consists of a flexible resistance bulb assembly, a meter, and an oil level selector, with the meter and selector enclosed in a meter housing for protection, while the bulb assembly is placed permanently inside the tank. The assembly operates on six direct volts, which may be supplied by dry cells or from a 115-volt a-c circuit by equipping the meter with a transformer and rectifier. Additional information may be obtained from the Weston Electrical Instrument Corporation, 641 Frelinghuysen Avenue, Newark 5, N. J.

Electronic Combustion Safeguard. A new electronic combustion safeguard system for commercial oil burners, which provides immediate cutoff of fuel in case of failure, has been announced by the General Electric Company's Control Divisions. The system, which includes a switch-amplifier-contactor unit, phototube holder, and electrode holder, assures protection against combustion failure because: (1) if the gas pilot does not ignite, the oil valve cannot open; (2) if the oil flame does not ignite, the supply of fuel is cut off. After the cutoff, the motor continues to operate for 30 seconds to purge the nozzle or cup of unburned fuel to prevent carbonizing and reduce field servicing. The system then is locked against further operation until manually reset. Upon resumption of service following a power failure, low water cutoff, or limit control operation during the starting cycle, the oil valve cannot open until the program switch recycles. When continued operation of the burner is prevented by ignition failure, a positive lockout mechanism is actuated and a light on the cabinet cover indicates that the equipment has gone to lockout. Operation cannot then be resumed until the reset button is pushed. A self-checking circuit prevents starting of the equipment unless the photoelectric detector, pilot protector,

(*Continued on page 48A*)

Kentucky Utilities Company, Inc.
chooses
Steel Towers
for 138 K. V. Single Circuit Line

● When Kentucky Utilities Company, Inc., selected American Bridge light steel towers for its 138 K.V. single circuit line, it found that these towers made possible more severe design conditions because they had sufficient strength to carry longitudinal, transverse and vertical loads. Also, Kentucky Utilities found that foundation erection was quicker and cheaper because the circular steel grillages of the towers were designed to permit machine boring of anchors. Conductors and ground wires were carried in the most economical spans and the exact arrangement desired. And, like most things made of steel, these towers have the stamina to provide extra years of service.

To help you take advantage of the outstanding superiority of steel for structures of this type, American Bridge Company makes available its experience and facilities for designing, fabricating and erecting. Why not submit any questions you might have to our nearest Contracting Office.

AMERICAN BRIDGE COMPANY

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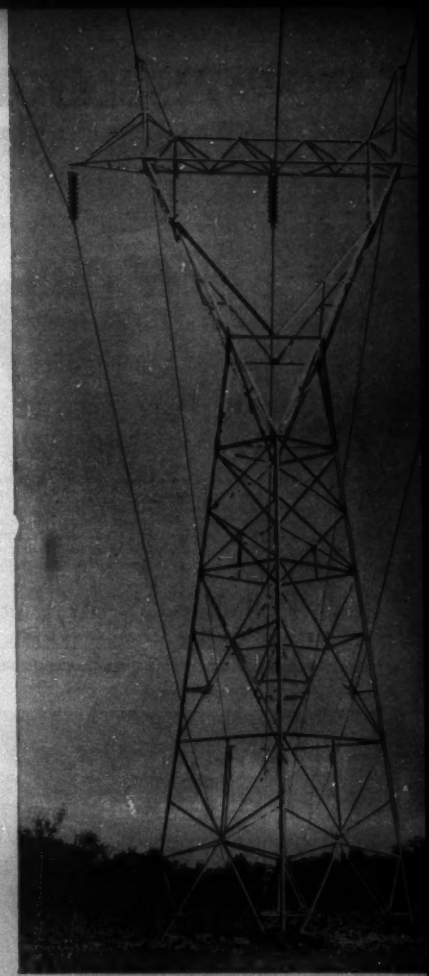
UNITED STATES STEEL EXPORT COMPANY, NEW YORK



Dix Dam—Green River line. Single circuit 138 K.V. rotated towers with three 556,500 C.M. conductors and two 7/16" ground wires. Length=140 miles.

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UNITED STATES STEEL

PORCELAIN INSULATORS THAT FIT YOUR NEEDS

This insulator half ring is an excellent example of Universal's ability to design and manufacture ceramic insulators to fit specific needs. In addition, it provides every quality of fine porcelain — uniform density of body, high dielectric factor, resistance to temperature extremes, physical shock, fumes, moisture, corrosion, smoke and acids. For insulators to fit your requirements, consult with Universal. An experienced engineer will be glad to assist you.

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TRADE MARK

New Electric Cable Cutter

$13.95 Post Paid

900 Available at Quantity Discounts

1. Original cost $70.00
2. Maximum Cap. 1 million Circ. Mils. or 2½" dia.
3. Will cut BX and other metal covered wire and cable up to 2½" dia.
4. Wt.—complete unit 11 lbs.

This unit is readily portable, or can be used as a stationary cutter by placing in a table vise. Cutter is equipped with reversible type ratchet and handle which drives powerful housed worm gear forcing wedge against cutter. Handle is detachable and gear box can be driven from either side. Blade is of high carbon steel and each unit is equipped with an extra blade. Body of cutter is made of high-quality forged steel. A real labor-saver—cuts heaviest cable with ease.

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AT LAST! AN OPEN-END RATCHET WRENCH — the world's first true *universal* wrench. A patented design for connections on tubing, rods, piping, conduit, studs, etc. Sixty-four socket sizes from ⅜" to 4". Smallest effective ratcheting arc yet — 5° to 7½°. TAC will also do every job any ordinary ratchet wrench will do: one TAC set replaces literally dozens of single-purpose hand tools.

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This publication will bring to the attention of electrical engineers designing interior systems for commercial buildings the important features involved in the design, which, if overlooked or improperly treated, may result in unnecessary limitations and inconveniences, as well as unsatisfactory performance of the illuminating and utilization equipment and of the communication and signaling facilities.

The report covers the basic features of electrical wiring applicable to all types of commercial buildings. It will serve as a guide to the young engineer when first he undertakes work of this character to help him avoid serious omissions and mistakes. This is not an AIEE Standard, and the recommendations are not intended to be mandatory or restrictive.

Prepared by the AIEE Subcommittee on Interior Wiring Design for Commercial Buildings of the Committee on Industrial Power Systems.

PRICE: $0.80 ($0.40 to AIEE members.)

Send orders to: Order Department,
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
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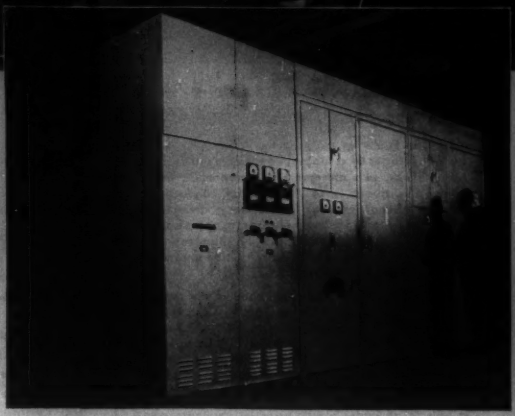
5-51

Cohoes, N. Y. protects pumping plant equipment

with G-E Limitamp high-voltage control

Recently, Cohoes installed a new 500-horsepower G-E synchronous motor on a raw water pump. Before they selected control the city engineers wisely decided on a complete study of the power supply. Working with the G-E sales engineer they determined the available short circuit capacity of the system was 60,000 kva. The destructive potentialities of this power obviously called for an "insurance" that would protect their investment.

G-E Limitamp was the "insurance". It answered every need. In addition to controlling the motor, its co-ordinated design, using current-limiting EJ-2 fuses, will clear shorts in less than half a cycle—well before damage can occur to motor or control. Extra dividends in the new smaller size, protection to personnel, reduced installation, engineering, and maintenance costs are inherent in this equipment, too.



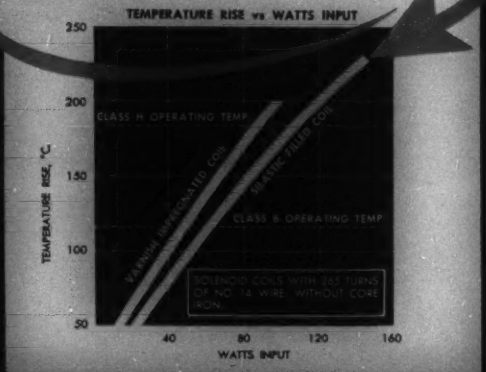
G-E Limitamp installed at Cohoes, N. Y. for control of two 500-horsepower motors

For your high-voltage installation ask for G-E Limitamp—now available in ratings up to 4800 volts with an interrupting capacity up to 250 mva. Protect your power system and motors with G-E Limitamp—more information in Bulletin GEA-5409. Ask the nearest G-E office for this bulletin or write Section 730-23, *Apparatus Dept., General Electric Company, Schenectady, N. Y.*

GENERAL ELECTRIC

730-23

SILASTIC* the resilient dielectric, stable from -60° to +200°C.



dissipates heat much faster than conventional insulating materials

Here's an insulating material that gives you all of the advantages of a rubberlike dielectric at Class H temperatures, plus extreme low temperature flexibility, plus about twice the thermal conductivity of conventional resinous or rubbery dielectrics! In a solenoid coil, for example (see graph above), Silastic gives 15% more capacity than resinous silicone insulation at 180°C. That's due to increased thermal conductivity alone.

Thermal stability plus high heat conductivity permit the Silastic coil to operate at 166% of the maximum capacity for an identical organic resin impregnated solenoid. Performance of over 1600 Silastic insulated main and interpole field coils in diesel-electric traction motors is further proof of the extraordinary advantages of Silastic as a dielectric.

In coils of all kinds, Silastic provides resiliency and relatively constant dielectric properties of temperatures ranging from below −60° to above 200°C., maximum resistance to corona, to electrical and mechanical fatigue and to abrasion, oil and outdoor weathering.

Silastic insulated solenoid has 166% of the capacity of identical Class B coil plus maximum shock, abrasion and vibration resistance over a span of 260 Centrigrade degrees from −60 to +200°C.

SEND TODAY! For data on the properties, performance and applications for Silastic.

(*T. M. Reg. U. S. Pat. Off.)

from +500°F. SILASTIC stays Elastic to −100°F.

DOW CORNING CORPORATION, DEPT. H-5, MIDLAND, MICH.

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THE WIDE BAND POCKETSCOPE®

BY WATERMAN

MODEL S-14-B

Wt. 14 lbs.
12" x 6" x 7"

Another Waterman POCKETSCOPE confirming the obsolescence of conventional oscilloscopes. Characterized by wide band amplifier fidelity without peaking as well as amazing portability. S-14-B POCKETSCOPE is ideal for laboratory and field investigation of transient signals, aperiodic pulses, or recurrent electrical wave forms.

Vertical channel: 50mv rms/inch, with response within −2DB from DC to 700KC, and pulse rise of 0.35μs. Horizontal channel: 0.3v rms/inch with response within −2DB from DC to 200KC, and pulse rise of 1.8μs. Non-frequency discriminating attenuators and gain controls, with internal calibration of trace amplitude. Repetitive or trigger time base, with linearization, from ½cps to 50KC, with ± sync. or trigger. Trace expansion. Filter graph screen. Mu metal shield. And a host of other features.

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CABLE ADDRESS: POKETSCOPE

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S-10-B GENERAL	POCKETSCOPE
S-11-A INDUSTRIAL	POCKETSCOPE
S-14-A HI-GAIN	POCKETSCOPE
S-15-A TWIN TUBE	POCKETSCOPE
S-21-A LINEAR TIME BASE	

Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC® TUBES and other equipment

WATERMAN PRODUCTS

ALL RANGES WITH THIS ONE CONTROL

Model 630

Just *one* knob—extra large—easy to turn—flush with the panel, controls all ranges. This one knob saves your time—minimizes the chances of "burn-outs" because you don't have to remember to set another control. You can work fast with Model 630 with your eyes as well as your hands. Look at that scale—wide open—easy to read, accurately. Yes, this is a *smooth TV* tester. Fast, safe, no projecting knobs, or jacks, or meter case. Get your hand on that single control and you'll see why thousands of "Model 630's" are already in use in almost every kind of electrical testing

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Standards on electric machinery and apparatus chiefly devoted to defining terms, conditions, and limits which characterize behavior, with special reference to acceptance tests.

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* Approved as American Standard

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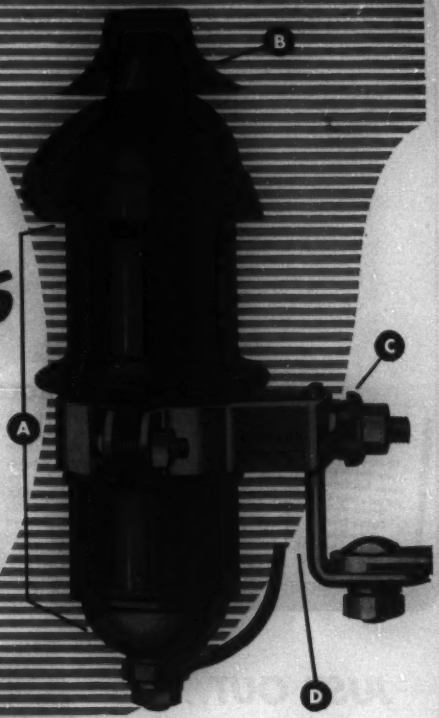
5-51

ALL THE AUTOGAP ADVANTAGES plus LINE TERMINAL INSULATION



HUBBARD Line Insulated Autogap Lightning Arresters are the answer for utilities who do not approve of exposed hot line terminals. When lines are worked hot, exposed terminals present a constant hazard, especially on congested poles. The insulated line terminal also prevents bird trouble.

Electrically, these insulated Autogaps have the same characteristics as other Hubbard Vertical Autogap Arresters. Salient points are indicated in the illustration. The line terminal at the top of the arrester is protected by a bakelite cap.

The external gap is between the arcing horn and the "L"-shaped extension of the grounded mounting bracket.

Standard EEI-NEMA mounting brackets are supplied—No. 2337 for Crossarm mounting or No. 2338 for Pole mounting.

A *TWIN EXHAUST an exclusive Autogap feature, assuring maximum surge capacity.*

B *Bakelite insulator cap covering line terminal.*

C *Ground terminal attachment.*

D *Air gap.*

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STANDARD SIGNAL GENERATOR

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MANUFACTURERS OF
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MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

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OUTPUT IMPEDANCE 50 ohms

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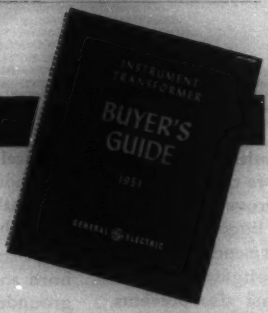
BOONTON NEW JERSEY

JUST OUT.....

1951 EDITION



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American Standard
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ELECTRICAL
QUANTITIES

This American Standard (Z10.5 — June 1949), which has been prepared by a subcommittee of the Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering, is a revision of ASA Z10g1 and AIEE 17g1.

General principles of letter symbol standardization, a typographical notation for distinguishing, in the equations of the printed page, between the symbols for scalar, complex (phasor), and vector quantities are given, as well as tabulations of the symbols in alphabetical order of the names of quantities, English letter symbols, and Greek letter symbols.

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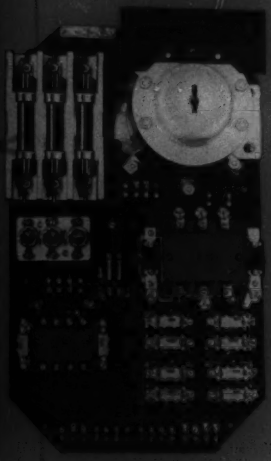
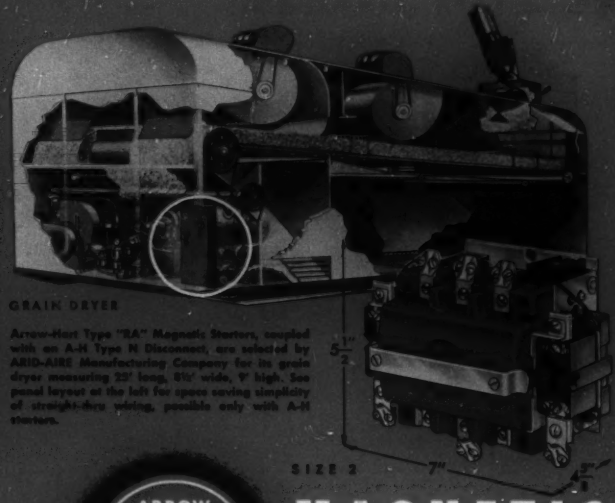
BRING OUT **BUILT-IN PERFORMANCE** OF MOTORS AND MACHINERY



CONTROL PANEL



GRAIN DRYER

Arrow-Hart Type "RA" Magnetic Starters, coupled with an A-H Type N Disconnect, are selected by ARID-AIRE Manufacturing Company for its grain dryer measuring 23' long, 8½' wide, 9' high. See panel layout at the left for space saving simplicity of straight-thru wiring, possible only with A-H starters.

5½"

7"

SIZE 2

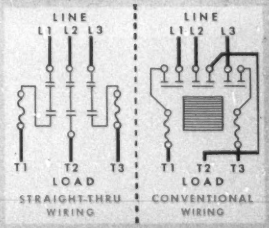
TYPE "RA"
RIGHT ANGLE

ARROW AH HART

MAGNETIC STARTERS

JUST 1/2 THE SPACE

PLUS STRAIGHT-THRU FRONT WIRING



Yes, to obtain maximum built-in performance from quality machines, use Arrow-Hart advanced design Type "RA" Magnetic Starters, smallest ever manufactured, first to give you ***straight-thru front wiring.*** This means faster, neater installations at savings up to 30%; safer, direct routing with greater separation of line and load; immediate identification of circuits; elimination of crossing, looping, U-bending; no need for a load terminal on the line side. This simplicity with versatility is ***not*** possible with solenoid or other type starters. Compare the connection diagrams to the right and on the reverse side for conclusive proof of the straight-thru wiring benefits of Arrow-Hart Magnetic Starters — the most logical controls to specify, buy, and use. Available in sizes 0, 1, 2, 3 and 4.

COMPARE!

Write for folder complete with design and operating features, dimensions, ratings and other pertinent data.

BUY WITH CONFIDENCE *PROFIT BY PERFORMANCE*

THE ARROW HART & HEGEMAN ELECTRIC COMPANY, HARTFORD, CONN., U. S. A.

ARROW AH HART

MORE BIG FEATURES IN JUST 1/2 THE SPACE!

ARROW AH HART

TYPE "RA" MAGNETIC STARTERS

Arrow-Hart Magnetic Starters occupy just 1/2 the space of conventional starters. This means an overall reduction in the size of the control panel and a substantial reduction of material costs. The exclusive "RA" mechanism sets a new standard for functional simplicity in design — a new and superb performance acclaimed by more and more original equipment designers and manufacturers, electricians and maintenance men.

Other features include high arc resistant and suppression chambers for each set of contacts; big, heavy duty copper contacts with special silver alloy tips; guided parallel closure of contacts; improved magnet and coil; precision calibrated relays. All parts are easy to reach, wire and service for outstanding performance and economy.

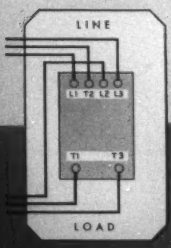
SIZE 2 ILLUSTRATED

MECHANISM DIMENSIONS
DEPTH — 4⅝" HEIGHT — 5½"
WIDTH INCL. RELAYS — 7"

COMPARE!

CONVENTIONAL WIRING

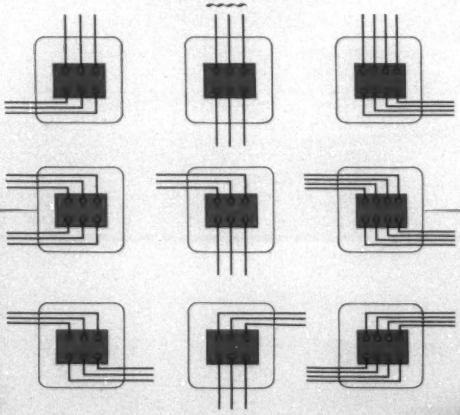
3 PHASE STARTER



An example of wiring reverse existing with old type solenoid starters. One load wire must be brought in to the line side.

ARROW-HART STRAIGHT-THRU FRONT WIRING

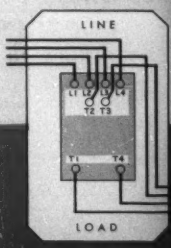
LINE OR LOAD



Arrow-Hart straight-thru wiring makes the most of installation and maintenance opportunities for space, time and work savings. Faster and neater layouts, direct routing without crossovers, immediate circuit identification are all plus performance features of the A-H advanced design.

CONVENTIONAL WIRING

2 PHASE 4 WIRE



Another example of scrambled wiring. Makes circuit identification more difficult and increases sequential errors.

Write today for folder and engineering data on Arrow-Hart Type "RA" Magnetic Starters and Contactors, complete with ratings, dimensions, and parts information. Available in local and remote control or selector switch types in sizes 0, 1, 2, 3 and 4. Consult your local electrical distributor or write the factory for engineering service. Field engineers are in your territory to assist you.

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NUMBER 7 OF A SERIES

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SOUTHERN UTILITY USES "TTR" TRANSFORMER TURN RATIO TEST SET

It is a routine practice of Duke Power Company to ratio power transformers when they are being conditioned for service.

Recently a bank of power transformers being moved to a new location were given a routine check with the Biddle TTR Test Set. The test indicated a fault in one of these transformers. Investigation revealed several shorted turns on the primary. Since the fused turns were not grounded the transformer had operated for some time without failure but with an unbalanced voltage and circulating current in the delta. Having discovered this fault with the TTR Test Set it was possible to repair the transformer without excessive cost or interruption of customer service.

The Biddle Transformer Turn Ratio Test Set is simple to use in the field and insures quick, easy, highly accurate readings. Operated by one man, it is completely self-contained, including 8-volt hand generator, test leads and clamps. Look into this excellent instrument investment and the savings it will mean to your company. Your request will bring by return mail *Bulletin 55-EE.*

Here's the NEW BIDDLE IMPULSE CABLE FAULT LOCATOR

NOW RATED UP TO 25 KV. WITH THESE IMPROVEMENTS

Higher Voltage—25 kv. increases its usefulness for proof, repair, and service tests on cable installations with voltage ratings up to 15 kv., as well as in cable fault locating.

Improved Performance of Detector—new techniques resulting from field experiences.

Current Measurements Now Included for Proof Testing—permitting the measurement of leakage or incipient fault current during proof testing; helps to determine the condition of cable and other electrical equipment.

Meets Needs for Locating Faults—on duct-installed cable up to 34.5 kv.

The Biddle Impulse Cable Fault Locator was developed primarily for locating faults on lead-covered cable installed in ducts. It has applications also on aerial and buried cable, and has proved highly effective in utility and industrial service. In operation, the set is essentially independent of the fault or its apparent resistance, and depends only on the impulse voltage required to break down the fault.

Equipment now in use in various industries has *scored high* in fault locating. *Keep in touch with us on Cable Fault Locating*—we will gladly consider your problems and give you full benefit of our own progress, development and experience.

For complete information, write for *Bulletin 65-EE.*

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Uniformity is

for resistors too!

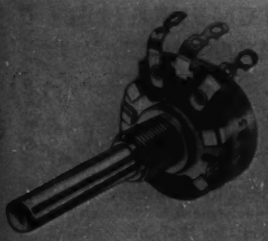
It isn't hard to make a resistor with specific characteristics. The trick is to make resistors by the million, fast and at low cost, and *still retain uniformity* in those characteristics. Specializing in resistors, IRC achieves this uniformity through mechanization of production, plus continuous inspection and rigid quality control. Result:—IRC customers are assured of identical resistance units—within prescribed limits—regardless of quantities or time of purchase.

Uniformity of IRC Advanced BT Resistors—which meet JAN-R-11 specifications—is the result of combining IRC's filament-type resistance elements with exclusive construction features. Resistance material is permanently cured and bonded to special glass. Leads extend into filament for rapid heat dissipation. Molded bakelite seals element against moisture and prevents grounding. In standard RMA Resistance Ranges, Advanced BT's possess extremely low operating temperature and excellent power dissipation at ⅛, ½, 1 and 2 watts.

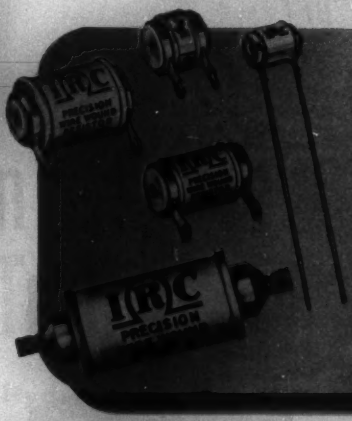
Full details of these compact, light-weight, fully insulated units are contained in 12-page technical data Bulletin B-1. Use coupon to send for your free copy.

IRC

important



Meticulous engineering and elimination of hand manufacturing operations assures maximum uniformity in these small 1⅛" Type Q Controls. Resistance element is the best IRC has ever manufactured. Increased arc of rotation permits same resistance ratios proved successful in previous larger IRC controls. Electrical rotation is the same with or without new IRC Type "76" switch. Catalog data Bulletin A-4 gives complete information.



Uniformly accurate and dependable, IRC Precision Wire Wounds excel in every significant characteristic. Leading instrument makers use them extensively for close tolerance applications. Winding forms are non-hygroscopic ceramic with high insulation qualities, high mechanical strength, low coefficient of expansion. Special humidity-proof enamelled-wire windings receive particular attention to avoid strain or breakdown in insulation. Standard 1.0% tolerance. ½, ¼ and 1/10% are available. Full details in catalog data Bulletin D-1.

Wherever the Circuit Says

prompt delivery of uniformly dependable standard resistors, in experimental or maintenance quantities, simply phone your local IRC Distributor. IRC's Industrial Service Plan keeps him fully stocked with the types and ranges—per-sizes he has to give you fast, round-the-corner delivery of small-order requirements. We'll be glad to send you his name and address.

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Please send me complete information on the items checked below:—

- ☐ Advanced BT Resistors (B-1)
- ☐ Type Q Control (A-4)
- ☐ Precision Wire Wounds (D-1)
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Standard RADIO INTERFERENCE and FIELD INTENSITY Measuring Equipment

Complete Frequency Coverage - 14 kc to 1000 mc!

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NM - 10A

14kc to 250kc

Commercial Equivalent of AN/URM-6.

Very low frequencies.

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Commercial Equivalent of AN/PRM-1.

Self-contained batteries. A.C. supply optional. Includes standard broadcast band, radio range, WWV, and communications frequencies.

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15mc to 400mc

Commercial Equivalent of TS-587/U.

Frequency range includes FM and TV Bands.

UHF!

375mc to 1000mc **NM - 50A**

Commercial Equivalent of AN/URM-17.

Frequency range includes Citizens Band and UHF color TV Band.

These instruments comply with test equipment requirements of such radio interference specifications as JAN-I-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others.

STODDART AIRCRAFT RADIO CO.

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Master Test Code for TEMPERATURE MEASUREMENT of Electric Apparatus

Upon suggestion by the Standards Committee of the AIEE, the Instruments and Measurements Committee voted in 1941 the appointment of a subcommittee for preparing a Master Test Code for Temperature Measurement. The objective of this action was to amplify, and ultimately replace by a single code, those recommendations on temperature measurement which are applicable to commercial tests on a variety of electric machines and which had been duplicated in separate standards pertaining to specific types of apparatus.

The recommendations in this completed and approved code (number 551, effective as of August 1950) apply to the determination of operating temperature and of temperature rise of all electric machines, instruments, and apparatus in common use, where temperatures do not exceed 500 degrees centigrade. Standards pertaining to permissible temperature rise and corrections are not included.

Price: $0.80 to non-members, $0.40 to members of the AIEE. Orders should be sent to:

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With Allis-Chalmers Hydrogen-Cooled Synchronous Condenser

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Whatever problem you may have in electrical power generation, distribution, control or regulation, your Allis-Chalmers representative can help you. For further information on Allis-Chalmers synchronous condensers, write Allis-Chalmers, Milwaukee 1, Wis., and ask for Bulletin 05B7285. A-3345

ALLIS-CHALMERS

This "gun" shoots wire around corners

Bell Telephone Company craftsman wraps a wire to complete a connection. Wire is inserted into the nozzle and a rotating spindle whips it around terminals.

Close-up of connection made with new tool—neat, tight windings.

IT DOESN'T take long to wrap a wire around a terminal and snip off the end. But *hundreds of millions* of such connections are being made each year to keep up with America's growing demand for telephone service.

Now this job is done much more efficiently with a new wire wrapping tool invented at Bell Telephone Laboratories. This "gun" whirls wire tightly around terminals before solder is applied. The connection is better and there is no excess wire to be clipped off — perhaps to drop among a maze of connections and cause trouble later.

The new tool is being developed in different forms for specialized uses. The hand-operated wrapper in the illustration is for the telephone man's tool kit. Power-driven wrappers developed by Western Electric, manufacturing unit of the Bell System, are speeding the production of telephone equipment. The gun's small nozzle reaches where fingers couldn't — a big advantage these days when efforts are being made to produce telephone system parts smaller as well as better.

Bell Telephone Laboratories scientists devise many special tools that help your telephone system to keep pace with service demands economically — keeping your telephone service one of today's best bargains.

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WORKING CONTINUALLY TO KEEP YOUR TELEPHONE SERVICE BIG IN VALUE AND LOW IN COST

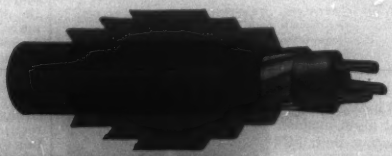
YOU S-T-R-E-T-C-H COPPER THIS WAY...

Unlike the housewife who uses bread crumbs and other materials to "stretch" the available supply of hamburger, Simplex is not able to add materials to copper to make it go further. We do achieve the same result, but by an entirely different means. Our way is to insulate the copper with Simplex-Anhydrex XX high voltage insulation. It is the very best "copper extender" that we know.

Simplex-Anhydrex XX is a product of Simplex research and development. It is an insulation that is absolutely "tops" in the high voltage field. It is designed to operate at a maximum of 167° to 176°F. (75° to 80°C.) copper temperature, depending on operating conditions. It has all the properties you want in such a high voltage rubber insulation. It will withstand heat. It also withstands ozone and aging, and it is guaranteed not to absorb more than 15 milligrams of water per square inch of exposed surface when tested in accordance with U. S. Coast Guard standards.

So far as we know it is the only insulation of its kind. Use it wherever you have a high voltage problem, whether the cables are to be installed directly in the earth, underground in ducts, under water, or overhead supported from messenger wire.

You can help to "s-t-r-e-t-c-h" the small available supply of copper by insisting that your high voltage cables be insulated with Simplex-Anhydrex XX insulation. Do you want to know more about this unique insulation? Then fill in the coupon below.



SIMPLEX-ANHYDREX XX

SIMPLEX WIRE & CABLE CO.
79 Sidney St., Cambridge 39, Mass.

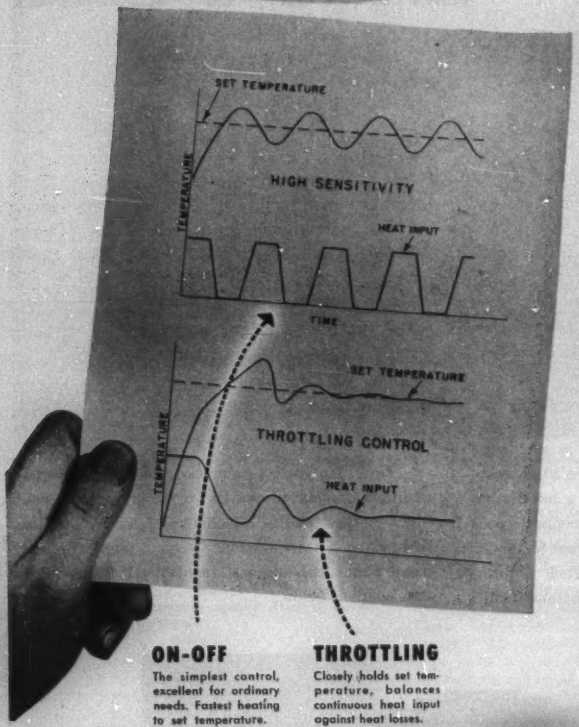
SIMPLEX WIRE & CABLE CO.
79 SIDNEY ST., CAMBRIDGE 39, MASS.
GENTLEMEN: PLEASE SEND A COPY OF BOOKLET 1009A TO:

NAME _____ TITLE _____
COMPANY _____
STREET _____
CITY _____ STATE _____

FOR *Consistent* CONTROL

Choose Characteristics to

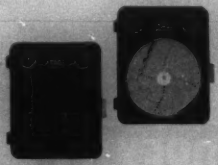
FIT YOUR CONDITIONS



ON-OFF
The simplest control, excellent for ordinary needs. Fastest heating to set temperature.

THROTTLING
Closely holds set temperature, balances continuous heat input against heat losses.

Furnaces heated by oil, gas or electricity can be accurately controlled with TAGliabue Pneumatic Controllers. On-off types give fastest heating; throttling types accurately balance heat input against losses to prevent overshooting or hunting. Both utilize an 18 p.s.i. air supply to operate diaphragm valves or power relays. Companion models control pressures along the same principles. Available as Indicating Controllers or as Recorder-Controllers. Write today for technical literature.



TAGLIABUE INSTRUMENTS DIVISION
WESTON ELECTRICAL INSTRUMENT CORPORATION
614 Frelinghuysen Avenue, Newark 5, New Jersey

Dielectric Moisture Meter Checks Various Materials

Moisture content of finely powdered, relatively dry, or coarse and oily materials is determined in less than two minutes with the versatile Model 8007 Dielectric Moisture Meter developed by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Operating over an extremely wide range, this meter functions without damaging the sample.

To use, a weighed sample is placed in a cell inserted in the instrument. The meter shows the material's capacitance, which simple tables convert into percent moisture. Chemicals, dehydrated foods, soaps, flours, seeds, plastic molding powders, iron ore, coal, cheese, coffee, corn, grain, dried leaf, flue dust, starch, yeast and cottonseed typify materials tested.

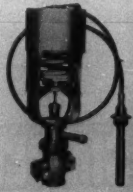
Weston Metal Thermometers Combine Precision, Stamina

Accurate, reliable temperature indication is given by the all-metal Thermometers manufactured by Weston Electrical Instrument Corp., Newark 5, N. J. These sturdy instruments are designed for utmost legibility and are constructed for use under severe operating conditions.

Weston All-Metal Thermometers can be supplied with the stem projecting from the back or from the bottom, top or side at any angle. Stem lengths from 2½" to 24" are standard; stems as long as 72" are available. A 3" dia. head provides a scale 6" long. Temperatures as low as —100°F. or as high as 1000°F. can be indicated. The "Max-Min" type records highest or lowest temperature since resetting. Contact making type closes an electrical circuit at an easily set value. Special models are also available.

Self-Operating Controllers Hold Precise Temperatures

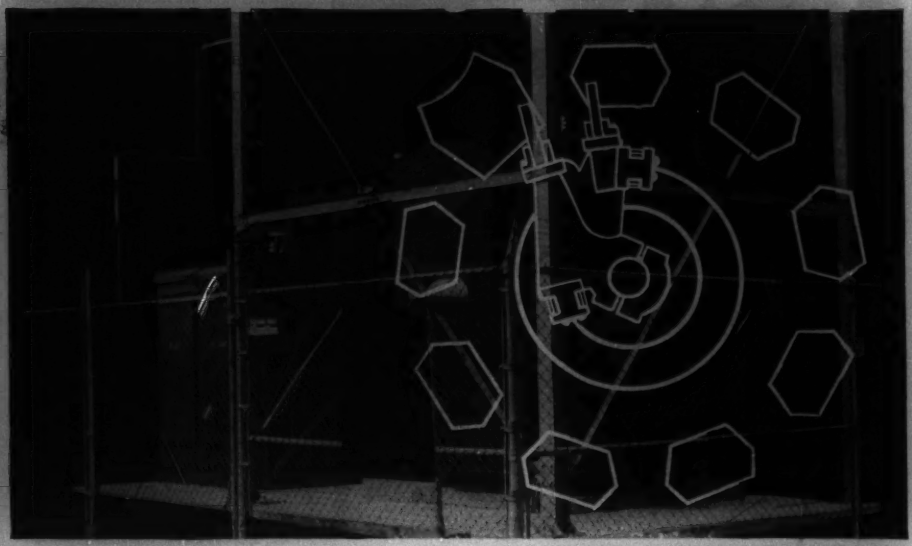
Temperatures between the limits of 20 and 300°F. are accurately maintained by the line of Self-Operating Controllers manufactured by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. These controllers are entirely self-contained, requiring no connection to any air or electrical power supply.



Available in styles for use on steam, hot water or refrigerant lines, TAG Self-Operating Controllers continuously adjust the supply of heating or cooling medium to maintain constant temperature despite changing thermal conditions. Typical applications include water heaters, tanks, retorts, washers, driers and pasteurizers.

ELIMINATE ALL ARCING

ON TAP SELECTOR SWITCH CONTACTS WITH . . .



. . . MOLONEY LOAD TAP CHANGERS PROVIDED ON FEEDER VOLTAGE REGULATORS, REGULATING TRANSFORMERS, LOAD RATIO CONTROL TRANSFORMERS

All Moloney Feeder Voltage Regulators, Regulating Transformers and Load Ratio Control Transformers are provided with Load Tap Changers which feature a load transfer switch to relieve the tap selector switch of all arcing duties. The load transfer switch has only four stationary contact tips per phase as compared with eighteen on the tap selector switch. This arrangement not only reduces the number of contacts subject to arc erosion, but also permits longer arc clearances to assure positive break of the arc. Liberal clearances of current carrying parts result in maximum capacity of the regulating equipment with minimum physical size. The load transfer switch, which is the only switch required to transfer load current, is provided with accelerating springs and is driven by Geneva gears. This assures quick break of the arc.

This is but one of the many features of the Moloney Load Tap Changer. This same sound basic construction is found in the regulating apparatus on which the tap changer is used.

Liberal clearances prevent establishment of an arc between adjacent current carrying contacts of the load transfer switch. Special alloy arcing tips prevent damage to the switch contacts as they are opened or closed.

MEMT-10

MOLONEY ELECTRIC COMPANY

Manufacturers of Power Transformers • Distribution Transformers • Load Ratio Control Transformers • Step Voltage Regulators • Unit Substations

SALES OFFICES IN ALL PRINCIPAL CITIES • FACTORIES AT ST. LOUIS, MO. AND TORONTO, ONT., CANADA

National Electric Coil Co. sleeving and tubing is braided in our plant, then varnish impregnated and baked under automatic control in this tower, designed by National engineers. Uniform high quality is insured. Just *try* it.

NATIONAL ELECTRIC COIL COMPANY
COLUMBUS 16, OHIO, U.S.A.

(*Continued from page 28A*)

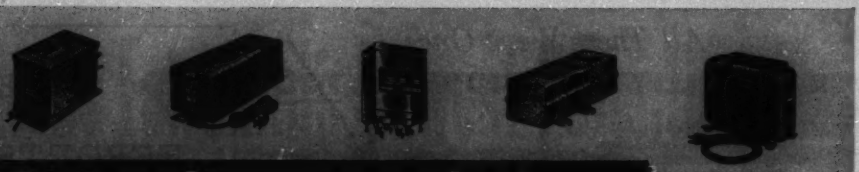
and electrode are in proper operating condition. The motor circuit is controlled directly by the built-in contactor for motor ratings up to and including one-half horsepower, 110 to 120 volts, single phase. Further information is available from the Apparatus News Bureau, General Electric Company, Schenectady 5, N. Y.

Aperiodic Power Amplifier. The General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., has developed a power amplifier, type *1233-A*, with three output combinations: (1) 20 cycles to 20 kc, into 150 or 600 ohms balanced or grounded. On this range, an output of 15 watts is available between 50 and 15,000 cycles; (2) 20 kc to 1.5 megacycles into 50 ohms, balanced or grounded. Maximum output is 15 watts from 20 kc to 0.5 megacycle; 8 watts at 1.5 megacycles; and (3) 20 cycles to 3 megacycles. Output is 150 volts peak-to-peak, for a high-impedance load with a gain of 60 decibels. With grounded output, voltage is limited to 50 volts, peak-to-peak, with a gain of 54 decibels. Rise time is approximately 0.1 microsecond, with negligible overshoot. Maximum output is obtained in all cases with an input of 0.2 volt. Distortion is below three per cent at maximum output over most of the frequency range, and noise is between 60 and 70 decibels below 15 watts. In addition to its use as a general laboratory or testing amplifier, type *1233-A* has applications in the driving of supersonic generators, the exciting of broadcast antennas for measurements with deflection-type instruments, and for use as an oscilloscope deflection amplifier. When used with an antenna and tuned input it can drive a modulation monitor to monitor remote transmitters. Additional details may be obtained from the General Radio Company.

Liquid Fire Extinguisher. A new one-gallon vaporizing liquid fire extinguisher named the Air-Flo has been developed by the Buffalo Fire Appliance Corporation, Dayton, Ohio. It operates on an entirely different principle in that dual air pumps build up internal air pressure which instantly forces the liquid out in a continuous steady stream up to 30 feet. It offers effective protection against electrical and flammable liquid fires. Internal corrosion is prevented by a new drying liquid, Dryex. Further information is available from the company.

Civil Defender Radio. A special frequency-modulated radio receiver for use by civil defense organizations having 2-way radio systems at their command has been announced by the General Electric Company. It is called the Civil Defender. The new receiver can be used by police agencies, fire departments, water departments, the Red Cross, and other groups comprising the civil defense organization. A novel feature of the unit allows civil

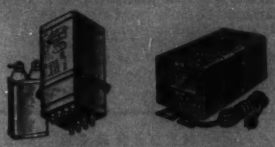
(*Continued on page 52A*)



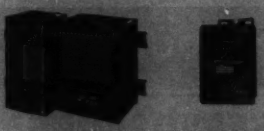
SOLA voltage regulation for Military Components

TYPICAL EXAMPLES

OF THE MANY REGULATING



TRANSFORMER TYPES



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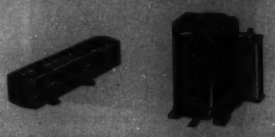

SOLA ELECTRIC CO.

Unfailing voltage control is vital to the performance of today's complex, sensitive electrical and electronic military devices. The manufacturer of such a device can insure its continuous optimum performance by "building in" a SOLA Constant Voltage Transformer to insure the proper input voltage required.

SOLA regulators are ideal for military use. They are rugged . . . completely automatic . . . instantaneous in response . . . have no moving or expandable parts . . . require no manual adjustment or maintenance . . . and are self-protecting against short circuit. The standard units will regulate secondary voltage output within ±1% regardless of continuous line voltage fluctuations as great as 30%.

In addition to line voltage regulation for 115 and 230 volt service, SOLA regulators are available in many special types such as: harmonic-neutralized units for commercial sine wave output; regulated plate and filament power supply transformers; adjustable, regulated A.C. voltage supplies; low voltage, high current filament transformers for oscillators and other large tubes.

The engineering skill and production facilities of the SOLA ELECTRIC CO., the world's largest manufacturer of constant voltage transformers, are available for defense production. SOLA regulators were purchased during World War II directly by the Signal Corps, Air Force and Navy as well as primary military contractors.

We invite your inquiries about standard and custom designed regulators, or the use of SOLA engineering and production facilities as a sub-contractor. Your request will be promptly answered.

SOLA *Constant Voltage* **TRANSFORMERS**

Transformers for Constant Voltage • Fluorescent Lighting • Cold Cathode Lighting • Airport Lighting • Series Lighting • Luminous Tube Signs Oil Burner Ignition • X-Ray • Power • Controls • Signal Systems • etc. • SOLA ELECTRIC CO., 4633 W. 16th Street, Chicago 50, Illinois

All These Were Once

DUST COLLECTION PROBLEMS, TOO

48 Carbon Black Plants
203 Metallurgical Installations
205 Acid Plants • 40 Paper Mills
270 Delarring Installations
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73 Steel Plants • 99 Oil Refineries
and Miscellaneous Installations

Your electrical precipitator installation will be individually engineered...and based on the Research Corporation's *experience* graphically shown by that towering pile of thousands of blue prints.

This knowledge is a valuable asset that will help Research engineers to "tailor-make" your Cottrell installation. For example, they can more quickly determine the right answers to such variables as the size, shape and type of both discharge and collecting electrodes, their relative spacing, flue arrangements and many other factors. At Research you can count on *profitable solutions to individual problems.*

Research Corporation Cottrells can be made as efficient as you desire. They can collect 95% to over 99% of all solid or liquid particles suspended in gas entering equipment. Write for free booklet giving valuable data. RC-121

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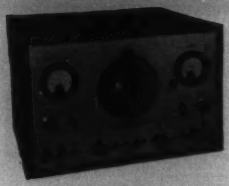
PRODUCTION LINE TESTING

OF

SERVOSCOPE®

SERVOMECHANISMS



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LONG ISLAND
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INVALUABLE IN RESEARCH

RAPID INSPECTION ON THE PRODUCTION LINE

A SERVO ANALYZER

- STANDARD RANGE: .1 TO 20 CYCLES PER SECOND
- SINE WAVE
- SQUARE WAVE
- MODULATED CARRIER 50 TO 800 CYCLES
- READS DIRECTLY SERVO LAG OR LEAD IN DEGREES

AIEE REPORTS

These publications are proposals for new standards or test codes, or revisions of present publications, which are in the formative stage.

They are made available, without cost, so that all interested individuals may obtain them for study and comment, thereby supplying practical experience in their use before submission for adoption.

22A Air Switches, Insulator Units, and Bus Supports (October 1949)

24 Protector Tubes (July 1940)

28A Valve and Expulsion Type Lightning Arresters (February 1950)

50 Automatic Circuit Reclosers for A-C Distribution Systems (September 1949)

51 Guiding Principles for Dielectric Tests (September 1949)

52 Application Guide for Grounding of Instrument Transformer Secondary Circuits and Cases. (March 1951)

502 Test Code for Single-Phase Motors (November 1941)

800 Test Code for D-C Aircraft Machines (March 1947)

801 Test Code for Aircraft Interrupting Devices (August 1950)

No charge for copies

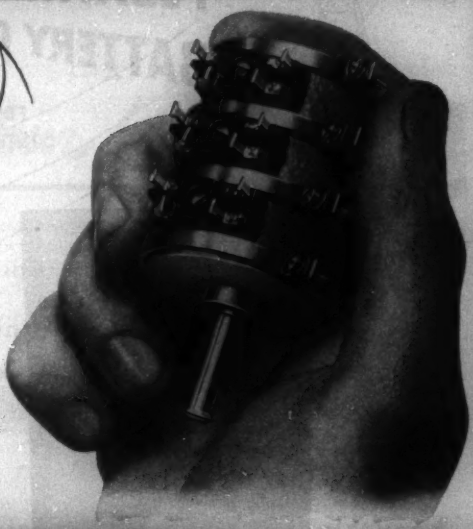
American Institute of Electrical Engineers
33 West 39th St., New York 18

5-51

Here's Fairchild's Newest Potentiometer!

TYPE-746 PRECISION POTENTIOMETER OFFERS:

- Low Torque
- Accurate Phasing
- Quick Replacement
- Ganging up to 20 on a shaft



The finest we've ever built! That's our idea of the new "746". It's got lower torque, a new more accurate phasing adjustment, and a new method of ganging that makes it easy to put as many as twenty cups on a single shaft. Individual cups in a gang are easily replaced if necessary.

The new potentiometer is available with linear or non-linear windings to meet your specifications. Its attractive case is made of grey anodized aluminum.

The "746" is just one of the complete Fairchild family of precision potentiometers. What are your requirements? Write, giving details, to *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N. Y.* Dept. 140-13L1.

EASY REPLACEMENT

To replace a unit in a "746" gang, loosen connecting-band screws, remove "cup," slip new "cup" under bands, and tighten screws. This feature pays off in experimental work where circuit elements are changed periodically.

ACCURATE PHASING

A new type phasing adjustment is simpler and more accurate. A retainer plate clamps shaft to wiper arm. To adjust for phasing, loosen two screws, set the arm to the correct position, then tighten screws.

FLEXIBLE DESIGN

Typical of the special consideration Fairchild gives to its customers' special requirements is this plug-in version of the "746." Where fast servicing is a must, the advantages of this "quick-change" unit are quite apparent.

SPECIFICATIONS

Accuracy (overall resistance)—±.5% (linear), ±1.0% or better (non-linear)

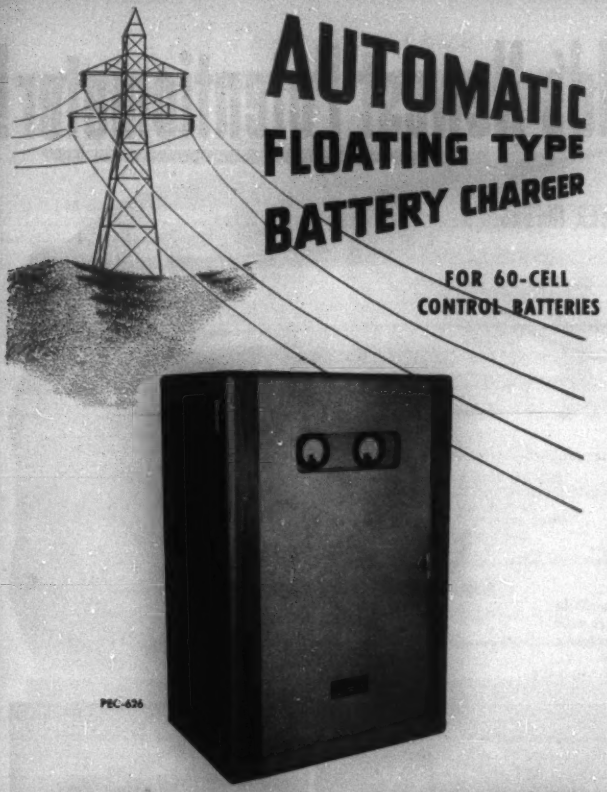
Mechanical accuracy—
concentricity (shaft to pilot)—.0015 in. FIR max.;
radial play—.0009 in. FIR max.;
shaft—centerless ground stainless steel to .2500 diam. (+.0000, —.0005 in.);
pilot hub—machined to .5000 (+.0000, —.0005 in.)

Torque—1.5 oz-in.

Dimensions—diameter 1.750 max.; length (1 cup) .800 in. ±.009 in.; added length per unit ganged .580 in. ±.002 in.

Case—grey anodized aluminum

FAIRCHILD
PRECISION POTENTIOMETERS



...gives you extreme accuracy and exceptional reliability

EXPRESSLY DESIGNED for unattended station service, the PEC-626 Automatic Battery Charger provides the extreme accuracy of electronic control plus the exceptional reliability demanded by this type of service.

In designing this unit, Power Equipment Company engineers started with the rugged components of a manual charger, added a magnetic system for coarse voltage control, then a simplified electronic system for fine voltage control.

The PECO Charger accurately floats the control battery of any power station or substation which has a reasonably constant switchboard load; furnishes power to the load and maintains a fully charged battery, ready for any emergency. DC output is sufficient to continuously charge 60 lead acid battery cells at 129 volts, at a maximum rate of 12 amperes, and is automatically regulated to within ±0.5 percent, for AC line voltage fluctuations of ±5 volts on a 230 volt circuit.

Exceptional reliability is shown by the fact that if the electronic control section should be disconnected, the magnetic control section will still automatically hold the output voltage to within ±3 percent of nominal voltage.

Write for specifications now!

POWER EQUIPMENT *Company*

Battery Chargers ☆ Battery Eliminators ☆ D.C. Power Supply Units ☆ Regulated Exciters ☆ and other Special Communications Equipment

55 ANTOINETTE ST. DETROIT 2, MICHIGAN

(*Continued from page 48A*)

defense headquarters to broadcast messages to all groups at once, or to separate groups individually. Each receiver is inactive until turned on by headquarters. In addition to receiving messages from headquarters, it can be used to automatically start and stop air raid sirens or other warning devices. The push of a button at headquarters broadcasts a special tone which, when received by the Civil Defender, operates a switch to activate the warning device system. When a message is received, a lamp lights on the receiver and remains lighted until turned off by the operator. Should he be away from the receiver, and upon returning see the lighted lamp, he would know a message was broadcast, and could check with headquarters. Two models are available: one will operate in the 30- to 50-megacycle band of the radio-frequency spectrum, and the other will operate in the 152- to 174-megacycle band. Both are designed to operate on standard 117 alternating volts. However, an inverter will be made available to permit operation from a 6-volt storage battery. The receivers are double conversion, superheterodyne types, with two separate crystal-controlled oscillators. Further information is available from the General Electric Company, Electronics Park, Syracuse, N. Y.

TRADE LITERATURE

Planned Lighting. "Planned Lighting for Industry" is the name of a comprehensive 47-page publication issued by the engineering division of General Electric's Lamp Department. Designated bulletin *LD-4*, it describes how to engineer lighting to various industrial tasks, discussing six principal lighting systems and the use of specific techniques for special needs. Single copies of *LD-4* are available through the Inquiry Bureau, Lamp Department, General Electric Company, Nela Park, Cleveland 12, Ohio.

Precision Test Equipment. The Polytechnic Research and Development Company has published a new 67-page catalogue, which contains descriptions of their test equipment. The catalogue is available from the company at 202 Tillary Street, Brooklyn 1, N. Y.

Air-Conditioning Guide. A planning guide for industrial air conditioning, booklet *B-5160*, has been announced as available from the Westinghouse Electric Corporation, Sturtevant Division, 200 Readville Street, Hyde Park, Boston 36, Mass.

High-Speed Motion Picture Cameras. Wollensak Optical Company, Industrial and Technical Division, has issued a catalogue containing information, specifications, and applications of the 8-, 16-, and 35-millimeter Fastax high-speed motion picture cameras and the 16-millimeter oscilloscope camera. The catalogue may be obtained from the company at Rochester 21, N. Y.

...Your best buy

Power cable installations consist of material — cable conduit fittings lugs — PLUS installation time

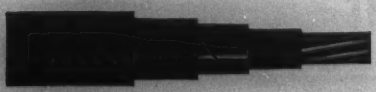
The MANHOURS required per installation are proportional to the weight of materials used.

ROCKBESTOS A.V.C.® carries more current.* Therefore you can use smaller—lighter cable conduit fittings lugs

The total weight to lift, hang, pull, is cut 1/3 and installation MANHOURS are materially reduced.

Q.E.D. ROCKBESTOS A.V.C. SAVES MANHOUR $

*National Electric Code—Chapter 10



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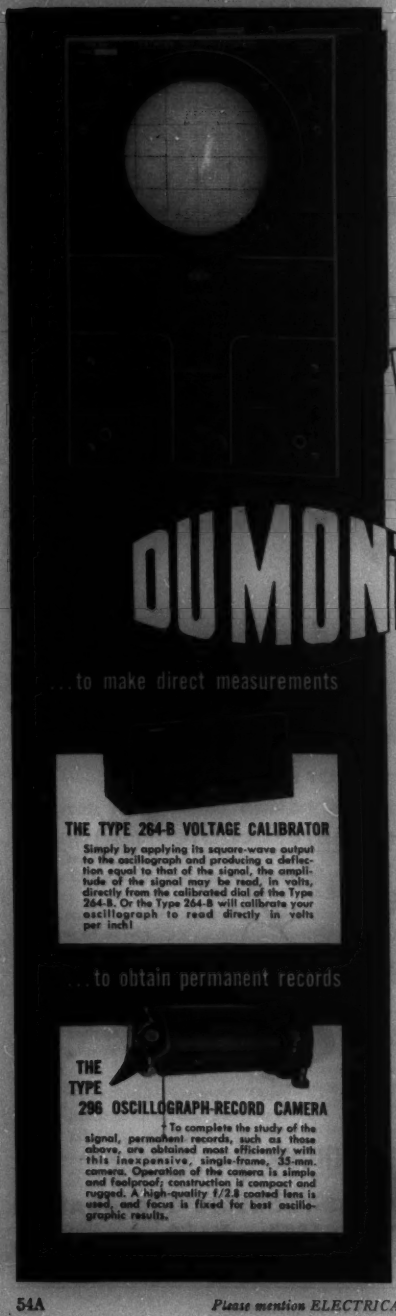


establish the signal's D-C LEVEL

...and measure its a-c and d-c components directly from the oscillograph

you should see...

Both a-c and d-c components are displayed through the d-c amplifiers of the Type 340-H. Base line represents zero volts.

The same signal, applied through a-c amplifiers exhibits a shifted reference line and tilt of the signal which make the oscillogram difficult to interpret.

DUMONT type 304-H

...to make direct measurements

THE TYPE 264-B VOLTAGE CALIBRATOR

Simply by applying its square-wave output to the oscillograph and producing a deflection equal to that of the signal, the amplitude of the signal may be read, in volts, directly from the calibrated dial of the Type 264-B. Or the Type 264-B will calibrate your oscillograph to read directly in volts per inch!

...to obtain permanent records

THE TYPE 296 OSCILLOGRAPH-RECORD CAMERA

To complete the study of the signal, permanent records, such as those above, are obtained most efficiently with this inexpensive, single-frame, 35-mm. camera. Operation of the camera is simple and foolproof; construction is compact and rugged. A high-quality f/2.8 coated lens is used, and focus is fixed for best oscillographic results.

The "Standard of Performance" for general-purpose cathode-ray oscillographs.

To study signals containing both a-c and d-c components, direct-coupled amplifiers such as those of the Type 304-H must be used. D-C amplifiers will maintain the true d-c level of the signal and display the actual relationship between the d-c and a-c components of the signal. Then by calibration of the Type 304-H with the Du Mont Type 264-B Voltage Calibrator, these components may be measured directly from the screen of the instrument.

Features such as driven sweeps, sweep expansion, extremely slow sweep speeds, and stabilized synchronization have made the Type 304-H the outstanding general-purpose cathode-ray oscillograph. Its sensitivity of 10 rms millivolts per inch and its versatility often eliminate the need for a second instrument to perform functions not within the range of the ordinary general-purpose oscillograph.

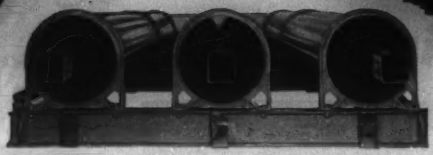
Portability contributes highly to the usefulness of the Type 304-H, especially in field work requiring good performance and in the laboratory where it serves many benches. The Type 304-H measures 13½" high, 8⅝" wide, 19" deep, and weighs only 50 pounds.

Write today for catalog...

Instrument Division, Allen B. Du Mont Labs., Inc.
1000 Main Avenue, Clifton, N. J., U. S. A.

DUMONT 20th YEAR AS PIONEER in Oscillography

REQUIREMENTS FOR A SET OF GENERATOR LEADS



ELECTRICALLY, THEY MUST

- carry the output with but one conductor per phase.
- not exceed a reasonable temperature rise.
- withstand overload without harmful effect to the conductor or its insulation.
- have a tight cover to prevent short circuiting by dust, moisture, etc., on the creepage surfaces of the insulators.
- have a minimum of bolted connections in bus run.
- protect against phase-to-phase short circuits.
- have insulation which is not harmed by heat or age.

MECHANICALLY, THEY MUST

- provide for expansion of bus and cover due to heat.
- withstand vibration.
- be adaptable to installation in congested areas.
- withstand thermal and mechanical stresses without damage or operating failure.
- employ porcelain and metals to their best advantage.

WHEN INSTALLED, THEY MUST

- present an attractive appearance.
- be easily put in place.

FOR INSPECTION AND MAINTENANCE, THEY MUST

- be easily accessible, permitting quick replacement of parts, particularly insulators.
- withstand periodic high-potential tests without damage to insulation.
- protect personnel who may come in contact with bus enclosure.

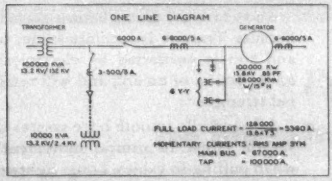
FOR ASSOCIATED EQUIPMENT, THEY MUST

- make provision for mounting disconnecting switches, instrument transformers, and protective devices.

I-T-E ISOLATED PHASE BUS MEETS ALL THESE REQUIREMENTS!

And it's as easy as this to order!

1. Give us a one-line diagram, like this —



2. Plus pertinent information about your building, generator, and transformers.

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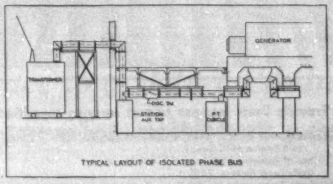

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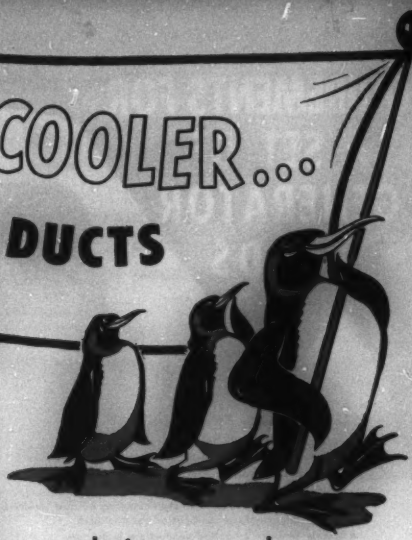

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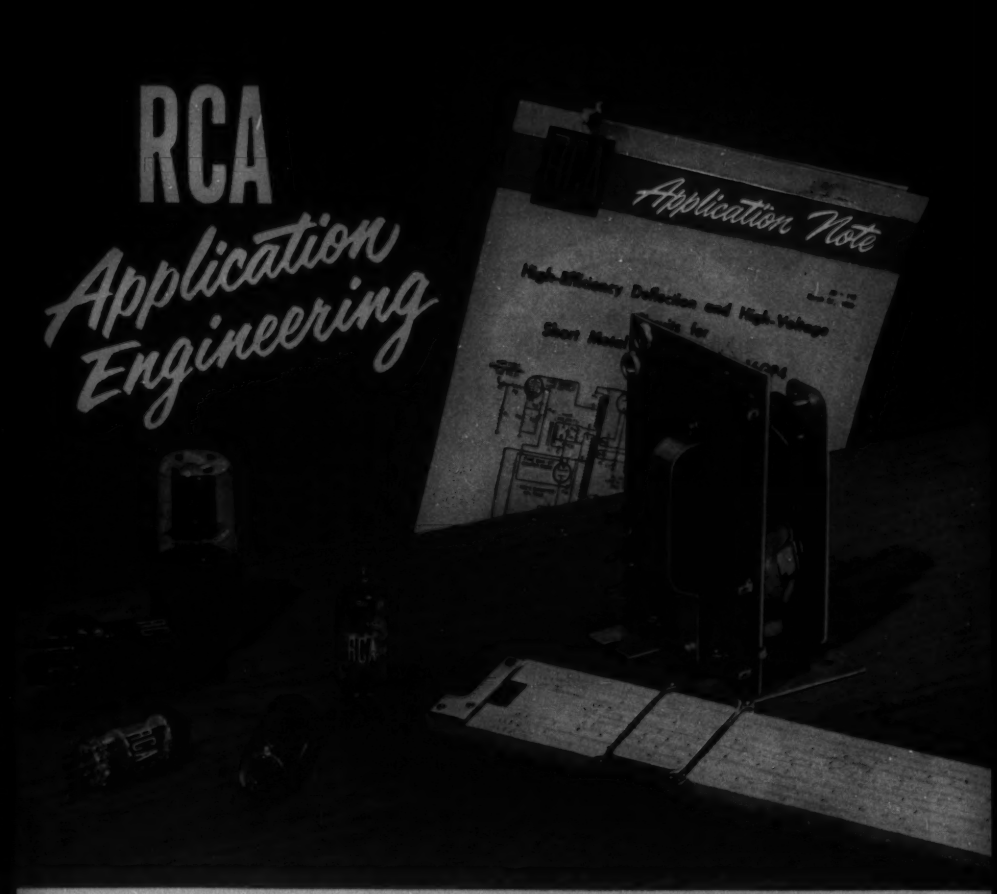

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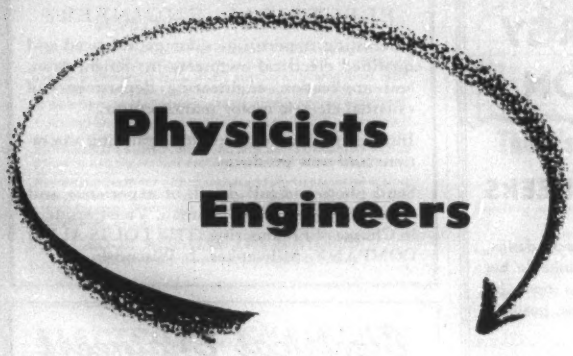

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PHYSICIST OR ELECTRICAL ENGINEER, 24–40, with degree and major in physics or electrical engineering, for research and development of ultrasonic transducers and special equipment for non-destructive testing by ultrasonic techniques; investigation of special methods of ultrasonic non-destructive testing; research and development of electro-mechanical devices for non-destructive testing. Minimum of two years' experience, now working in a university or industrial laboratory. Knowledge of piezoelectric properties, electronic amplifiers, and laboratory instruments for research and development in the field of ultrasonics. Salary, $4992–$7738 a year. Location, Connecticut. Y-4988.

PROFESSOR AND HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING with degree in electrical engineering, including generation, transmission and distribution of electric power. Must have good experience in the design and manufacture of electrical machinery for large hydro-electric and thermal power stations; or in lieu of a degree, must be thoroughly conversant with the design, development, execution, and maintenance of large electric generation and transmission projects, and must have at least ten years' experience in teaching electrical engineering as a professor and with practical experience in electrical industry or projects. Experience in original research work. Salary, $6000–$8400 a year. Location, India. Y-5005.

ENGINEERS. (a) Electrical Procurement Man, 35–45, electrical graduate, with varied experience, including electrical construction work, purchase of electrical equipment and materials, some inspection and expediting of electrical equipment. Some power house company experience desirable. Must be willing to make occasional trips to European countries for inspection purposes. Salary, $6000 a year. (b) Transmission Line and Sub-station Engineers with considerable experience on the construction of such work, with some college training and capable of assuming responsibility. Salary, $6000 a year. (d) Electrical Construction Engineer, with some college training and considerable experience in the construction and erection of generators, transformers, switchgear, control equipment, transmission lines, and sub-stations. Should be capable of assuming considerable responsibility. Salary, $7200 a year. Headquarters, Massachusetts. Y-5008.

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PROFESSOR in electrical engineering, to teach communications and electronics. Should, preferably, be about 40 years old; Ph.D. degree. Opportunity to become head of department within one year. Location, New England. Y-5189(a).

DESIGN AND DEVELOPMENT ENGINEER, electrical graduate, with at least four years' experience with circuit and systems covering analogue computers, radar, or industrial application of television techniques. Salary $6000–$8000 a year. Location, suburban New Jersey. Y-5208(a).

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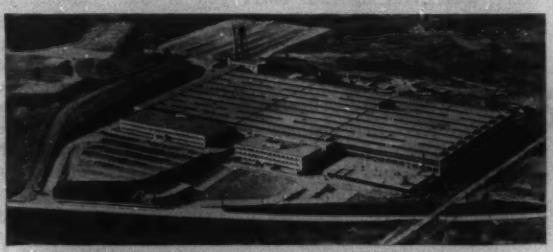

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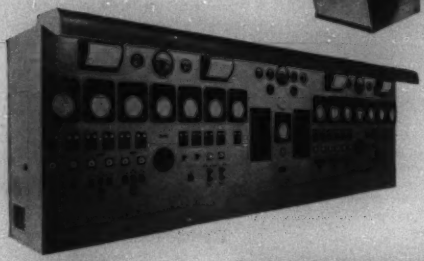

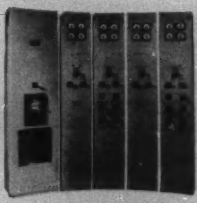

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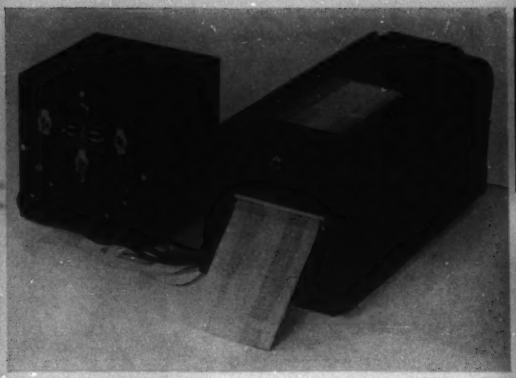

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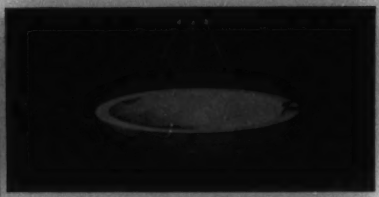

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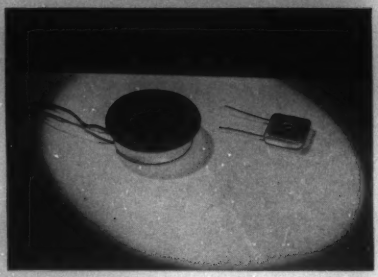

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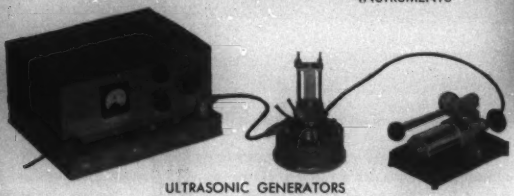

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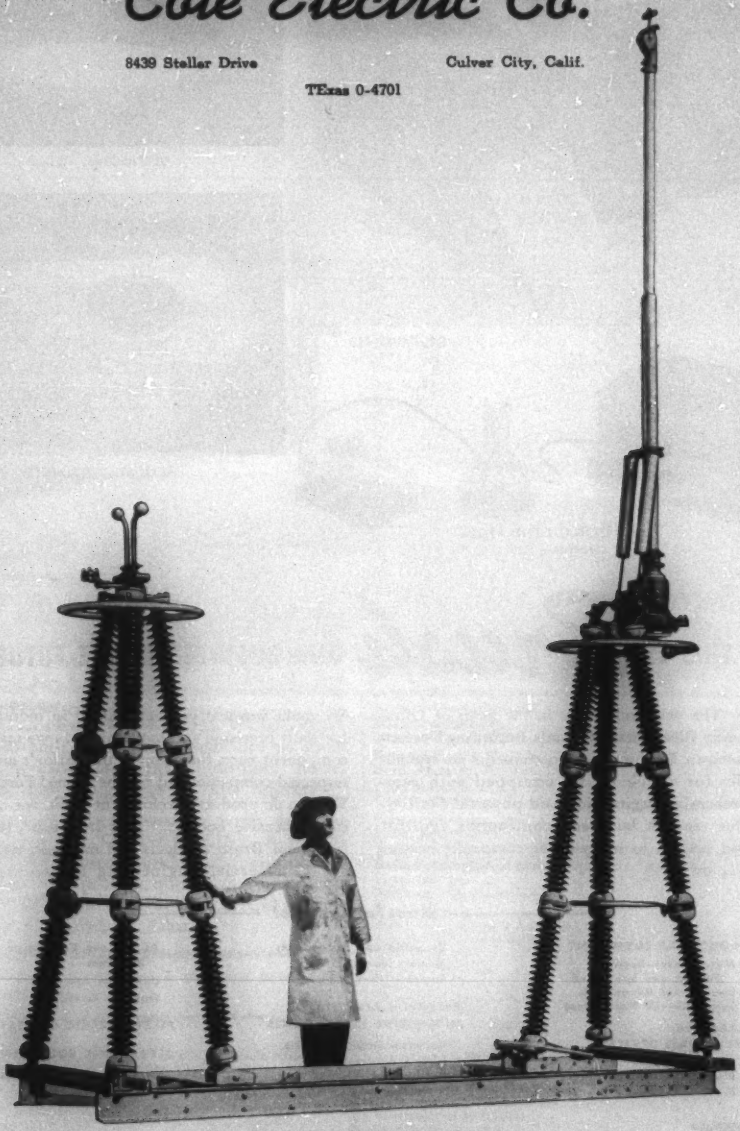

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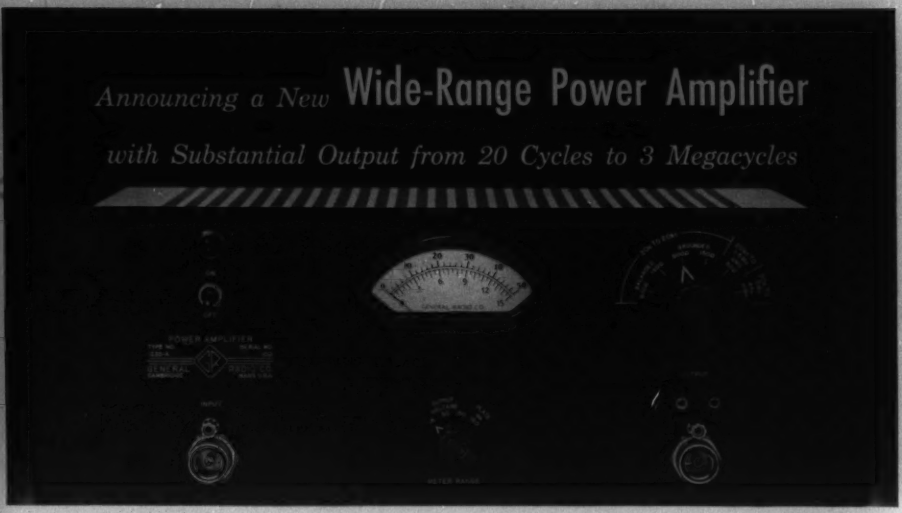

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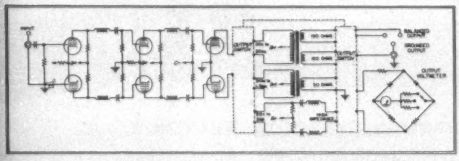

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